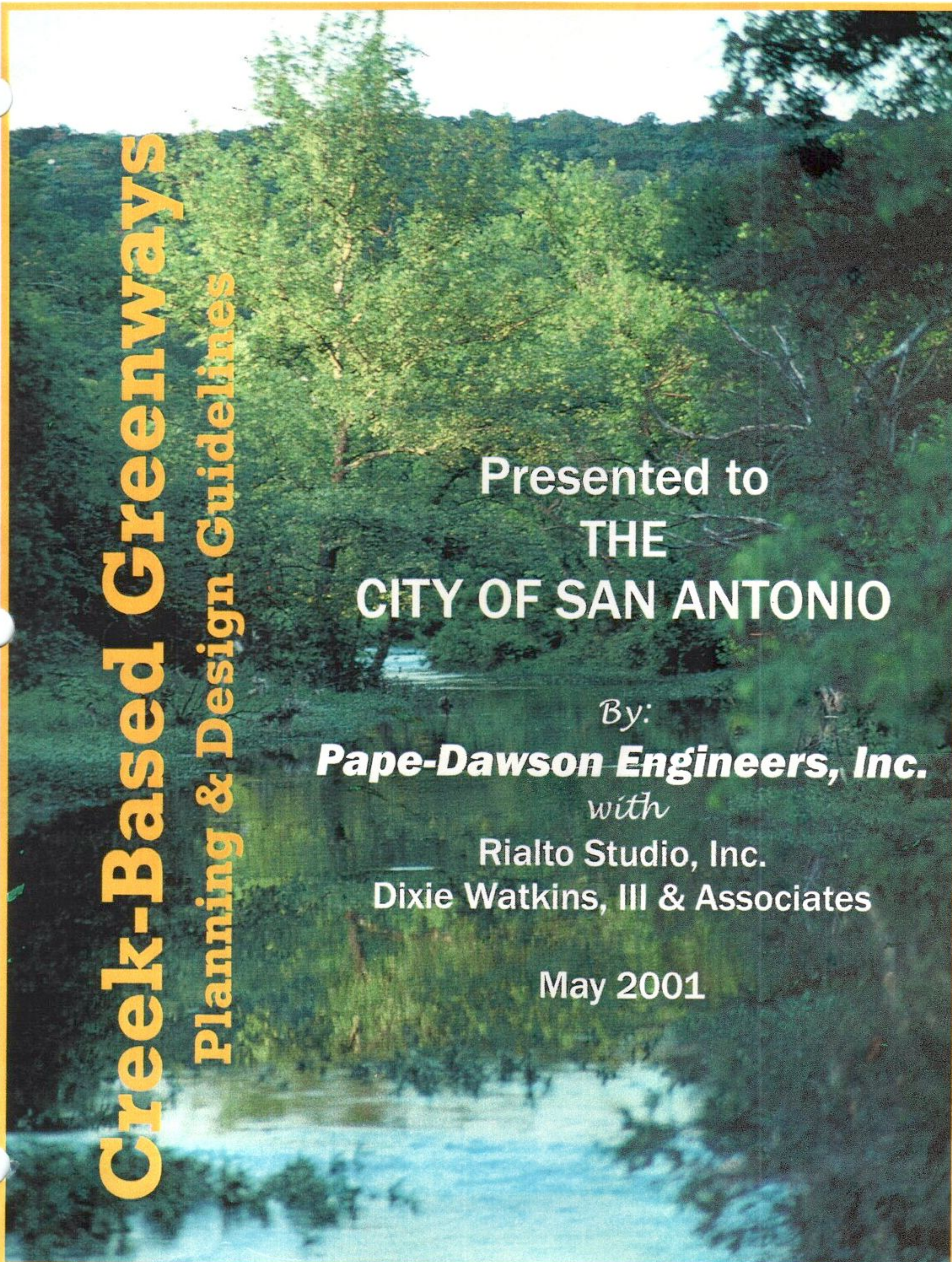

Creek-Based Greenways
Planning & Design Guidelines

Presented to
THE
CITY OF SAN ANTONIO

By:
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with
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May 2001

PLANNING AND DESIGN GUIDELINES FOR CREEK-BASED GREENWAYS

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PLANNING AND DESIGN GUIDELINES FOR CREEK-BASED GREENWAYS

I. EXECUTIVE SUMMARY

A creek-based greenway is defined as a linear open space established along a natural or manmade creek, or other drainage way, that is put to appropriate recreational use. A strategic goal of the City of San Antonio Parks and Recreation Department is to construct a network of creek-based greenways throughout Bexar County. By utilizing a combination of creek-based greenways and as many other open space opportunities as possible, linkages between communities, parks, and other various facilities will be created. A greenway network will provide a fundamental framework for improving and enhancing the quality of life for everyone in the region. Recognizing that storm water management is the primary function of the creeks and drainage ways in San Antonio, it is the intent of this project that greenway design and implementation complement regional and local storm water management, to their mutual benefit.

In order to provide a common strategy and to promote consistency in the development of creek-based greenways, planning and design guidelines are required. In developing the guidelines, the Design Team identified a set of goals for the project:

- Complement regional and local storm water management
- Promote a multi-objective approach to project design and implementation
- Provide a baseline for design and development of all creek-based greenways
- Enhance the appearance and function of San Antonio's greenways
- Conserve and respect natural processes and resources

An integral part of the project is its multi-objective focus, so that – ultimately - greenway development pairs the wisest use of resources with benefits to the most people. The major components of the multi-objective approach are:

- Facilitating better storm water management
- Providing new and varied recreational opportunities
- Maintaining and enhancing water quality
- Protecting aquifer recharge and sensitive karst components
- Facilitating neighborhood revitalization and inner-city development
- Conserving and interpreting cultural resources
- Protecting natural resources and habitat
- Restoring and rejuvenating existing drainage channels
- Providing opportunities for outdoor education
- Providing alternative transportation corridors
- Developing stronger community pride
- Lowering crime rates in greenway corridors
- Providing economic development opportunities

The project document is comprised of two main sections. The first section guides understanding of creek-based greenways and provides a planning approach and methodology. The second is a guide for design, including criteria for physical development of greenways.

Implementation of creek-based greenways will require active participation from the community and close coordination and cooperation between the City's Parks and Recreation Department, Public Works Department, Planning Department, and other key players. This document is an official component of the San Antonio Parks and Recreation System Plan (1999).

II. PLANNING

II. PLANNING

Planning for a creek-based greenway involves an evaluation of the characteristics and assets of the creek and the enhancements that can be made and are desired by the community. Storm water management is the primary function of creeks and drainage ways in San Antonio. Every other use of these facilities, including greenways, is secondary to the primary function of storm water management. Consequently, the planning process must also consider safety of users as it relates to flash flooding along trail segments. Assets of a particular stretch of creek or a network of creeks and drainages may be existing ones, past assets that have been lost through development or environmental impact, or potential assets that have not yet been realized. All pertinent components that may affect the planning and design - positively or negatively - need to be considered early in the process.

Along with the primary physical analysis, each greenway segment must also be evaluated with respect to applicable local plans and policies. There are numerous planning efforts that have taken place in San Antonio that may impact planning of a creek-based greenway. Major guidance can be found in:

- Adopted Neighborhood Plans of San Antonio
- San Antonio Master Plan Policies
- San Antonio Parks and Recreation System Plan
- Open Space Plan
- Water Quality Ordinance
- Regional Storm Water Master Plans
- Unified Development Code

In addition, there are other regional, state, and national policies, laws and requirements that may apply. For instance, the planning level might involve habitat analysis for compliance with the Endangered Species Act. The design will require compliance with the Americans with Disabilities Act. In addition, any work planned within the 100-year floodplain must receive a floodplain permit from Storm Water Utility and submit documentation as required by the EPA in accordance with the Storm Water Compliance for Construction Activity Ordinance. Design must be in compliance with floodplain management policies and consider hydraulic and hydrological impacts. The consultant should reference the City's floodplain ordinances for guidance. This section attempts to present the major requirements for planning a creek-based greenway. Of course, each project may have its own additional unique characteristics to be considered.

A. REGIONAL CONTEXT AND CHARACTERISTICS

Understanding Creek Systems

Each creek-based greenway to be evaluated can be generally described as belonging to one or more of three natural regions that make up Bexar County. For many of the region's creeks, that description can vary even within a particular segment. In greenway planning these described segments are defined between both natural and man-made nodes.

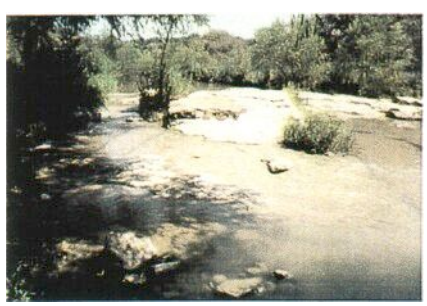
Creek systems are generalized as beginning at their headwater origins. These can be a single spring in the head of a box canyon, or where the intermittent stream designation is first shown on a U.S.G.S. map. The second node, heading downstream, is simply to the next tributary's confluence point. In terms of both watershed and greenway planning, it is convenient to identify these segments. But, in an urban and developing watershed, man-made features and in-channel impacts can also be used as nodes. These can be road crossings, dams, lakes or the beginning of improved channels. The first step in the planning process is to identify a segment or segments of creek that define the project.

In addition to the longitudinal dynamics, the width of the creek system is also important. The most critical foundation for creek-based greenway planning is a working knowledge of stream channel and floodplain dynamics. Whether in conservation or restoration projects, understanding the various ecological niches, landform, and adjacent terrain, is fundamental in defining the boundaries for a creek-based greenway. Even within relatively short creek segments there may be several types of erosional and depositional zones, vegetation, and unique geologic features.

Perhaps the most important definitions to know in understanding creek systems are the floodplain and channel.

- *The floodplain is the total area inundated (covered) by water for a given size storm.*
- *The channel is the area which carries the majority of the water during the same storm.*

Source: Dixie Watkins, III & Associates



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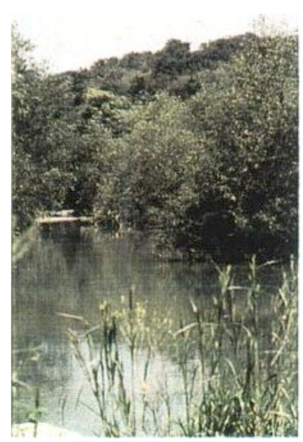

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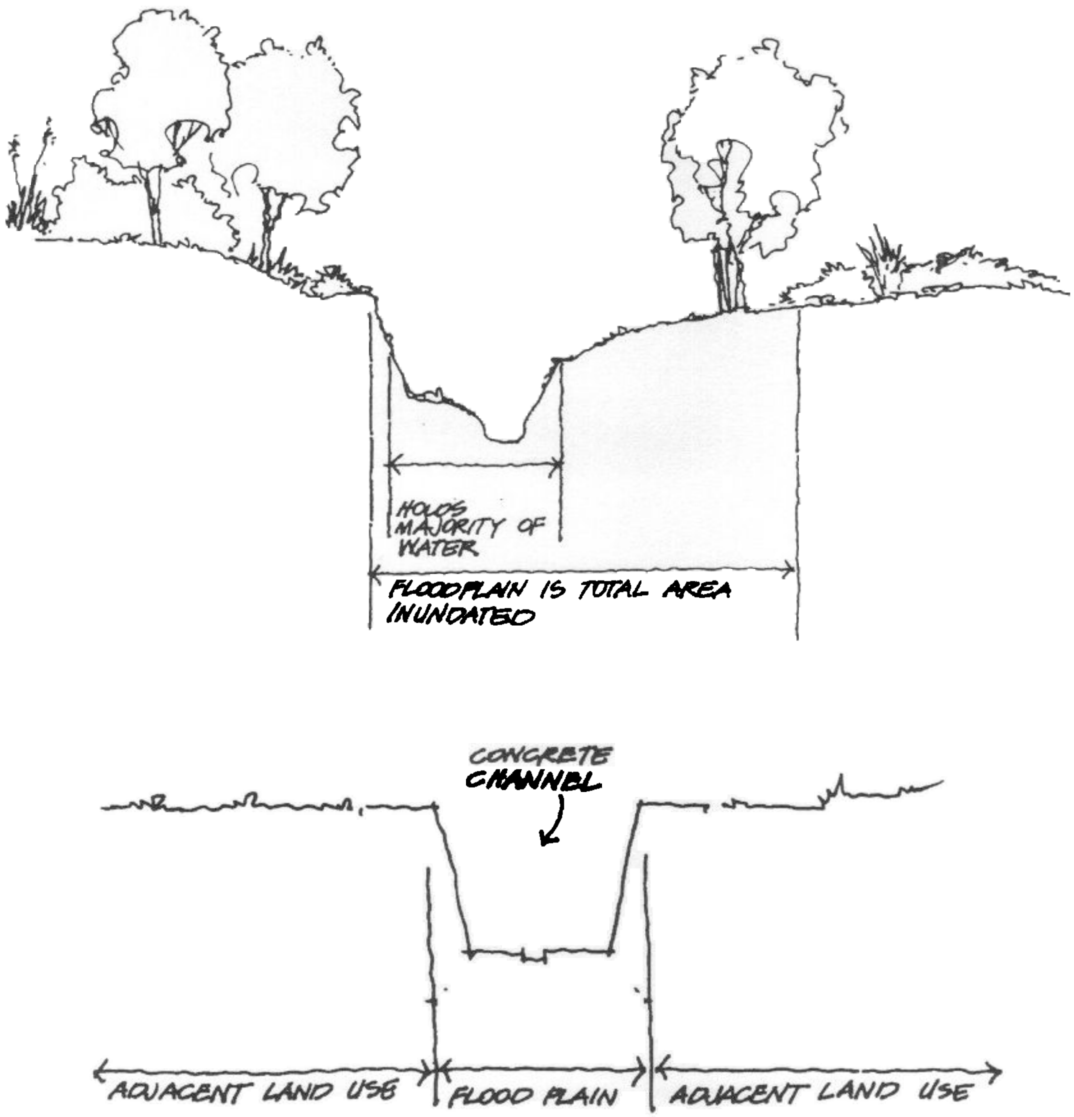


Figures 1 and 2: Channel and Floodplain Areas
Source: Pape-Dawson Engineers, Inc.

The Creek Channel

- Unvegetated Streambed
- Man-made Concrete or Earthen Channel
- Eroded Lower Banks
- Adjacent Vegetated Banks
- Adjacent Bluffs, Ledges and Cliffs
- Hardened Unvegetative Bottom
- Well-established Vegetative Channel Bottom
- Highest Velocities of Flood Waters

- Will include all of floodplain in urban engineered channel
- May contain only the channel or less in a natural system
- Contains most small frequency rain events

The Creekside Zone

- Just outside the channel
- Riparian and/or Vegetated Edges
- Vegetated Terraces
- Adjacent Landforms (Erosional and Depositional)
- Adjacent Public or Private Development, Streets, Utility Corridors, etc.
- Slower Velocities of Flood Waters due to Irregular Topography and Vegetation
- Storm Drainage Structures and Outlets from Tributaries

Middle Zone

- 100-year Floodplain
- Adjacent Landforms and Development
- Contiguous Wetlands
- Contiguous Storm Water Detention Areas (both natural and man-made)
- Significant Habitat
- Adjacent Public or Private Development, Streets, Utility Corridors, etc.
- Slowest Velocities of Flood Waters

Outer Zone-Buffers

More natural creeks also have outer-zone buffer areas. There are significant benefits provided by even minimal buffers, including:

- An average buffer width of 100 feet protects up to 5% of watershed area from future development.
- Reduce small drainage problems and complaints. When properties are located too close to a stream, residents are likely to experience and complain about backyard flooding, standing water, and bank erosion. A buffer greatly reduces complaints.
- Stream "right-of-way" allows for lateral movement of the stream. Most stream channels naturally shift or widen over time; a buffer protects both the stream and nearby properties.
- Effective flood control. Other, expensive flood controls may not be necessary if the buffer includes the 100-year floodplain.
- Protection from streambank erosion. Tree roots consolidate the soils of floodplain and stream banks, reducing the potential for severe bank erosion. Buffer zones with significant trees will reduce streambank erosion.
- Increase property values. Homebuyers perceive buffers as attractive amenities to the community.

- Increase pollutant removal. Buffers can provide effective filtering of storm water runoff from development located adjacent to the buffer boundary.
- Provide food and habitat for wildlife. Leaf litter is the base food source for many stream ecosystems; forests also provide woody debris that creates cover and habitat structure for aquatic insects and fish.
- Mitigate stream warming. Shading by the tree canopy in a buffer prevents further stream warming in urban watersheds.
- Protect associated wetlands. A wide stream buffer can include wetlands that are frequently found along the stream corridor.
- Preserve important habitat. Riparian corridors are important transition zones, rich in species. A mile of stream buffer can provide 25-40 acres of habitat area.
- Provide corridors for habitat conservation. Unbroken stream buffers provide corridors for migration of plant and animal populations.
- Provide essential habitat for amphibians. Amphibians require both aquatic and terrestrial habitats and are dependent on riparian environments to complete their life cycle.
- Discourage excessive storm drain enclosures/channel hardening. Can protect headwater streams from extensive modification.
- Provide space for storm water ponds. When properly placed, structural best management practices within the buffer can be an ideal location for Best Management Practices that remove pollutants and control flows from urban areas.
- Allowance for future restoration. Even a modest buffer provides space and access for future stream restoration, bank stabilization, or reforestation.

Natural-Physiographic Context

Bexar County may generally be divided into three geologic regions.

Edwards Plateau – Balcones Canyonlands
Creeks and floodplains of the north and northwestern portions of Bexar County are characterized as mostly perennial streams, which flow only after rainfall events or from springs and seeps. The exposed limestone bed and banks are as critical to the Trinity and Glen Rose aquifers as to the more sensitive Edwards aquifer. Dominant streamside vegetation is composed mostly of juniper-oak-cedar elm savannah, with riparian components of sycamore, willow, rough-leafed dogwood, and mulberry. Special endemic species, which vary with slope and orientation, include black cherry, black walnut, redbud, and ash, among others.

From fairly broad gravel channels between hills, to modest canyons characterized by alternating low cliffs, this "hill country" section contains many characteristics that should be considered assets and that may affect greenway prioritization:

- Microclimates where steep facing slopes harbor unique dells of plant and animal communities.
- Caves and karst features
- Significant recharge features
- Prehistoric rock shelter sites
- Endangered species habitat

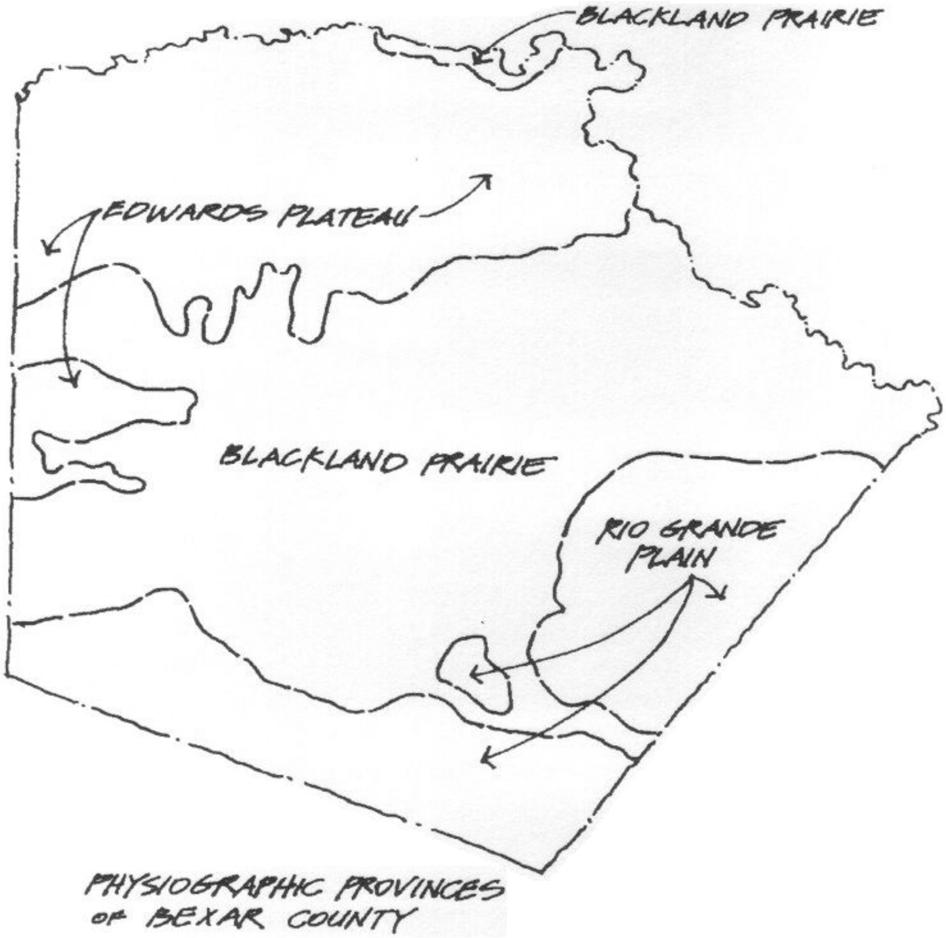


Figure 3: Physiographic Regions of Bexar County
Source: Dixie Watkins, III

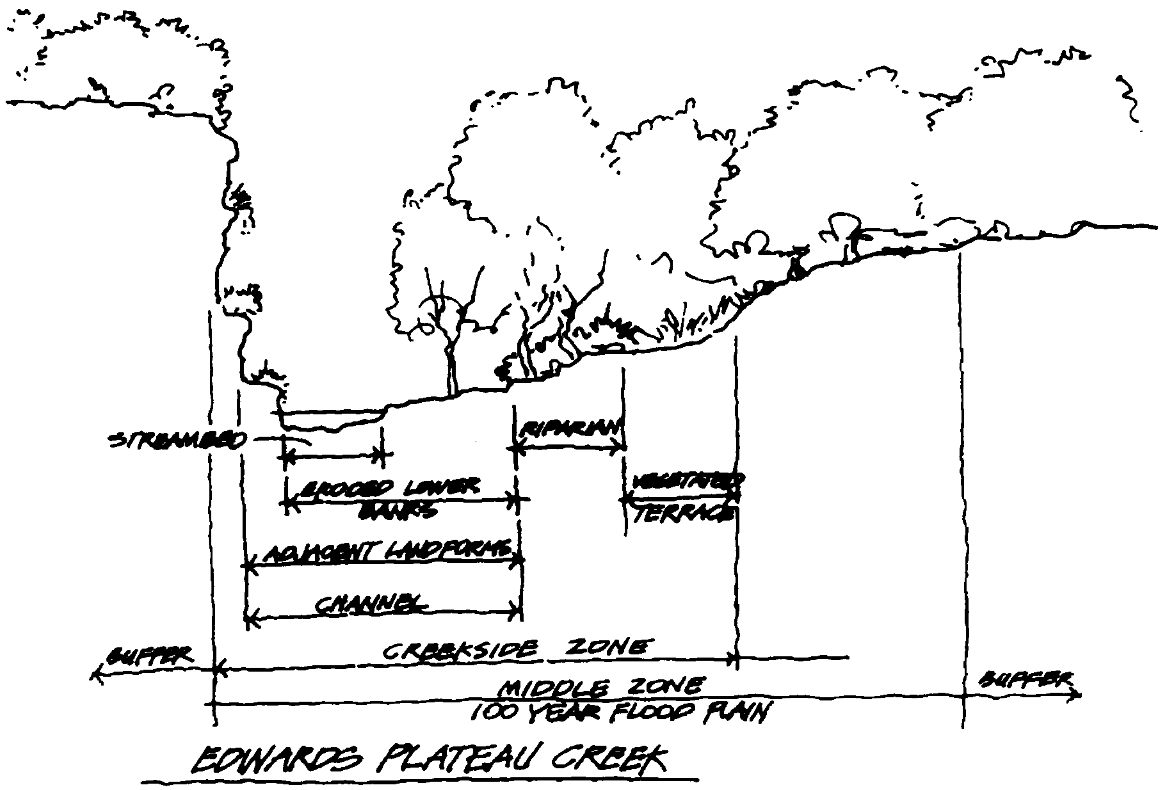


Figure 4: Edwards Plateau-Balcones Canyonlands: Typical Section
Source: Dixie Watkins, III

Blackland Prairie – Transitional

The deep, rolling topography of this area is from the thick older deposits of what was eroded out of the canyonlands and hill country. As such, the creeks of this section vary from being similar to those of the plateau, to deeply cut beds with highly erodable banks, numerous in-channel deposits, and broader floodplains. The clay and gravelly clay soils give rise to increasingly different dominant species proceeding downstream. Hill country species can still be found in these segments, but pecan, boxelder, hackberry, willow, cottonwood and cedar elm become more dominant. Flanking these corridors are remnant prairie grasslands.

The primary assets of this region are:

- Historic trails and roads
- Battlefields
- Culturally significant sites
- Endemic and unique plant communities

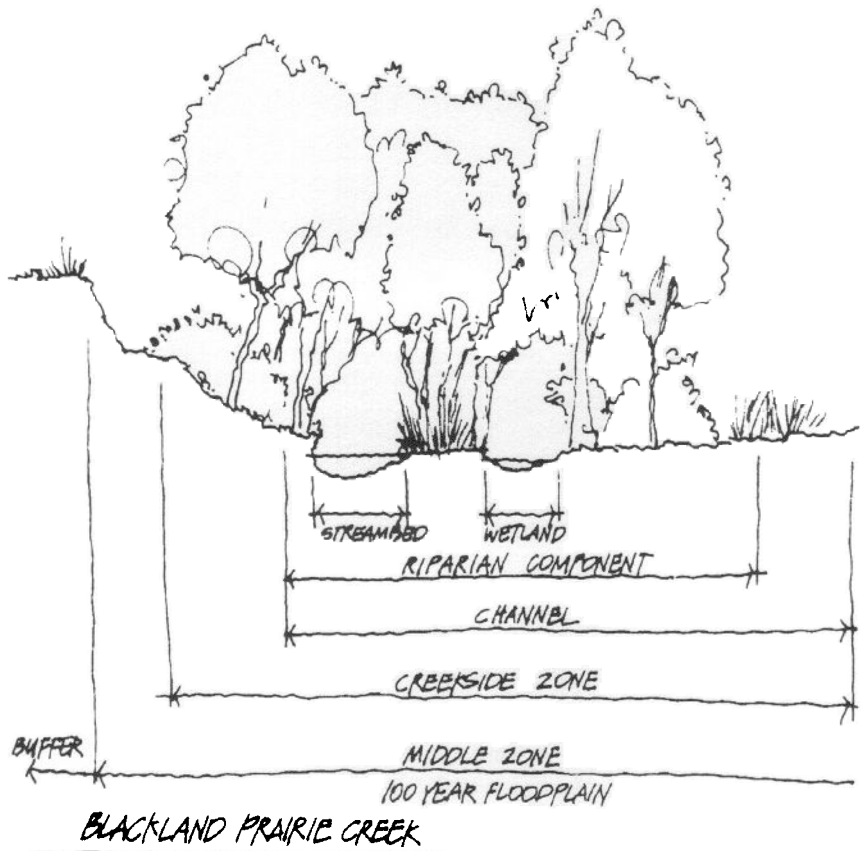


Figure 5: Blackland Prairie-Transitional: Typical Section
Source: Dixie Watkins, III

Rio Grande – Coastal Plain

The southwestern and southern parts of Bexar County contain a mix of sandy and mixed clay soils that vary significantly and are derived from younger geologic deposits. The riparian components in these segments contain most of what is common in the Blackland Prairie province along with more mulberry and willow species and some bald cypress. Adjacent regimes vary significantly, from South Texas scrub, to Post Oak-Hickory belts, to Live Oak motts with remnant short grasses. The primary assets of this region are generally the same as those of the Blackland Prairie.

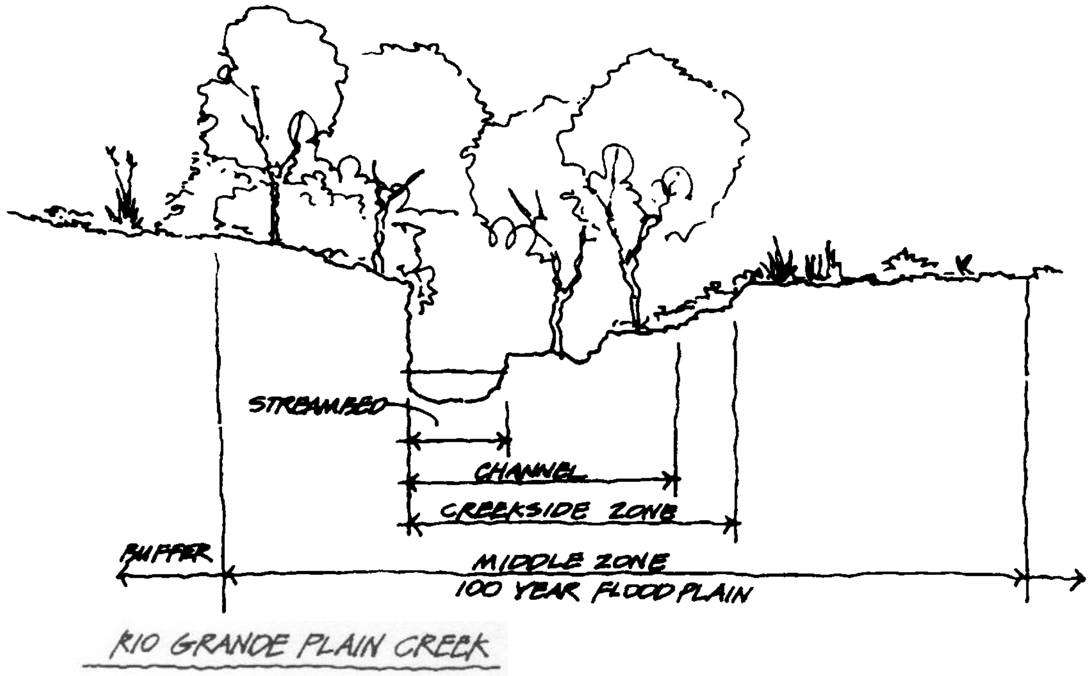


Figure 6: Rio Grande Coastal Plain: Typical Section
Source: Dixie Watkins, III

Development Context

Stream channel and floodplain dynamics vary significantly, in both the natural context and the degree of development in the project area. The type of land use, intensity of development, amount of impervious surfaces, and adjacent topography within each catchment area and subwatershed greatly affect the energies and impacts on each segment. Planning a creek-based greenway requires that the development context of the creek in the project area be identified. More than one context may apply.

The degree of ecological impact on streams in San Antonio worsens generally from the northwest portion of Bexar County towards the developing edges into the urban core. However, many of the creeks, by virtue of their broad floodplains and vegetated banks, show a marked healing as they pass on further to the south and east. In broad terms of both planning and ecological variables, these generalized creek settings, and their level of management plans, are shown in Table 1.

Development Context	Channel	Floodplain Character	Greenway Management Goal
Urban	Concrete & man-made earthen channels	Highly impacted to denuded	Enhancement/ Reconstruction
Suburban	Man-made earthen channels, concrete channels & natural streams	Patchwork to highly-impacted	Restoration/ Reconstruction/ Conservation
Rural	Semi-natural streams	Moderately impacted	Conservation/ Preservation
Undeveloped	Natural	Natural	Preservation

Table 1: Development Context
Source: Dixie Watkins, III

Urban

The existing urban context should not preclude the development and continuation of creek-based greenways. The goal of planning and design in these areas will be to restore natural and cultural resources which have been diminished through development. The greatest challenge will be to incorporate existing streets and drainage structures and the built environment into the greenway design. In a highly urbanized setting where the creek is channelized and fronted on both sides by development, the creek-based greenway trail system will have to leave the creek alignment and follow local streets, utility easements, abandoned railroad right-of-way, and other open spaces, in order to provide continuity.

Park development should build upon and not have a negative impact on the existing drainage system, which in an urban setting will likely be engineered. The urbanization of waterways results in two primary physical characteristics: increased impervious cover and channelization of natural streams. Impervious surfaces such as rooftops, and pavements accelerate the runoff of rain water which increases velocities and causes erosion and sediment transport to the receiving streams. Paved surfaces and rooftops also absorb more heat than landscape and natural areas and can therefore raise the temperature of storm water runoff. Increased temperatures in the receiving streams will affect the biota in the stream. If possible, greenway projects should include returning some impervious areas back into landscaped natural ground. For example, a large parking lot adjacent to a drainageway could be retrofitted with a landscape buffer.

Whereas natural streams have varying widths, depths, and textures, engineered channels are uniformly dimensioned and smooth. This results in a constant and generally faster velocity of storm water in the channel which precludes pockets of aquatic plants and animals. The tradeoff between man-made and natural streams is that while man-made streams do not support plants and wildlife, they convey floodwaters through an area without impacting the areas outside the channel. Natural streams will spread floodwaters out over a larger area. This allows for storage of the flood, slows the velocities of the floodwaters but impacts sometimes large areas. When planning a greenway project in an urban setting, one must weigh the impacts (pros and cons) of natural and man-made streams in the project area.

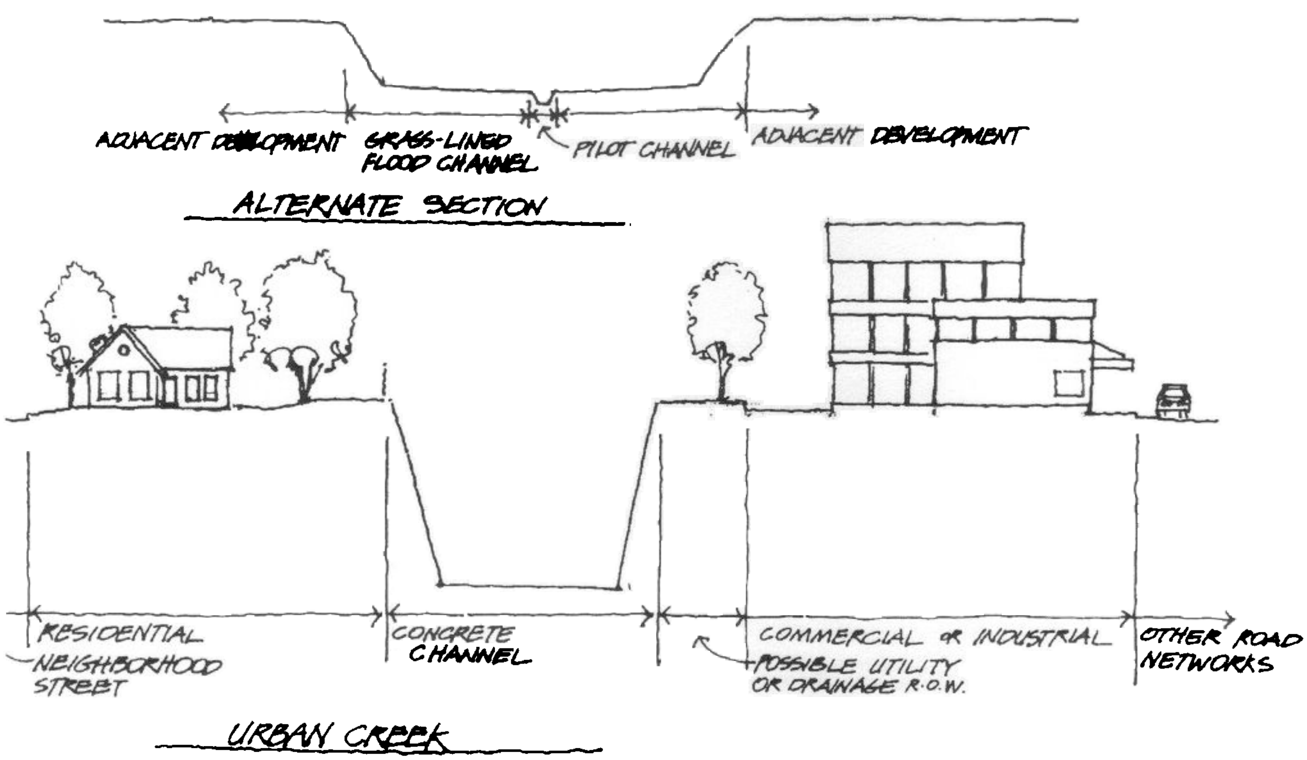
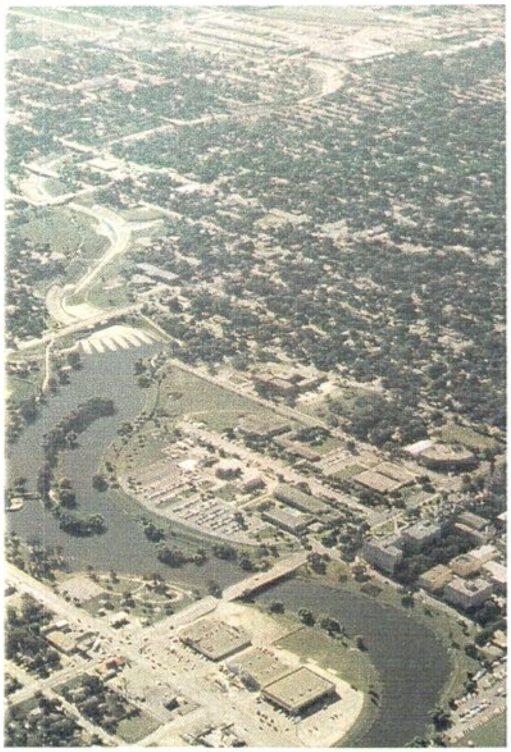


Figure 7: Urban Creeks
Source: Pape-Dawson Engineers, Inc.

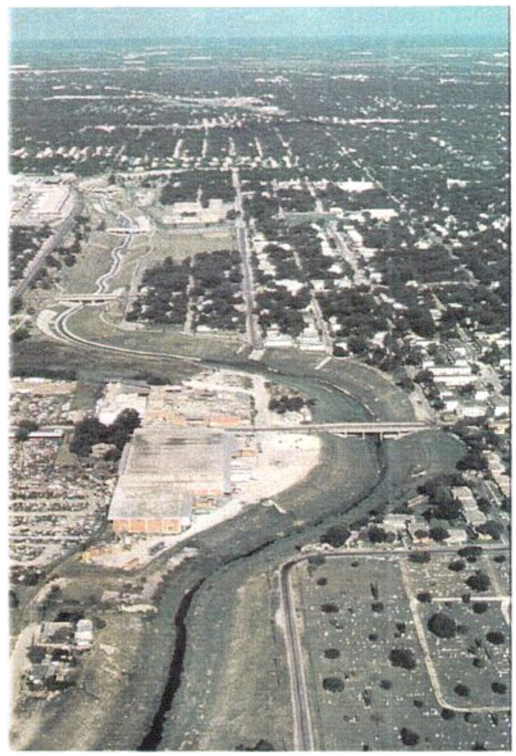
The urban setting may pose the following planning and design challenges:

- Dense development adjacent to existing and channelized drainage ways.
- Lack of existing vegetation to screen and enhance a greenway and lack of space to re-establish such vegetation.
- Small and large drainage structures crossing the greenway must be incorporated.
- Greenways may need to incorporate regional storm water detention. However, the space available for regional storm water detention will be smaller in existing urban developments.
- Existing utility corridors may already occupy some of the space being planned for a greenway.

- Utility corridors may be used for trail alignments in developed urban areas.
- Scenic drives may be created with existing less-utilized streets along the edge of the floodplain.
- Lack of right-of-way.
- Existing undersized drainage facilities.



Creek Context
Source: Dixie Watkins, III & Associates



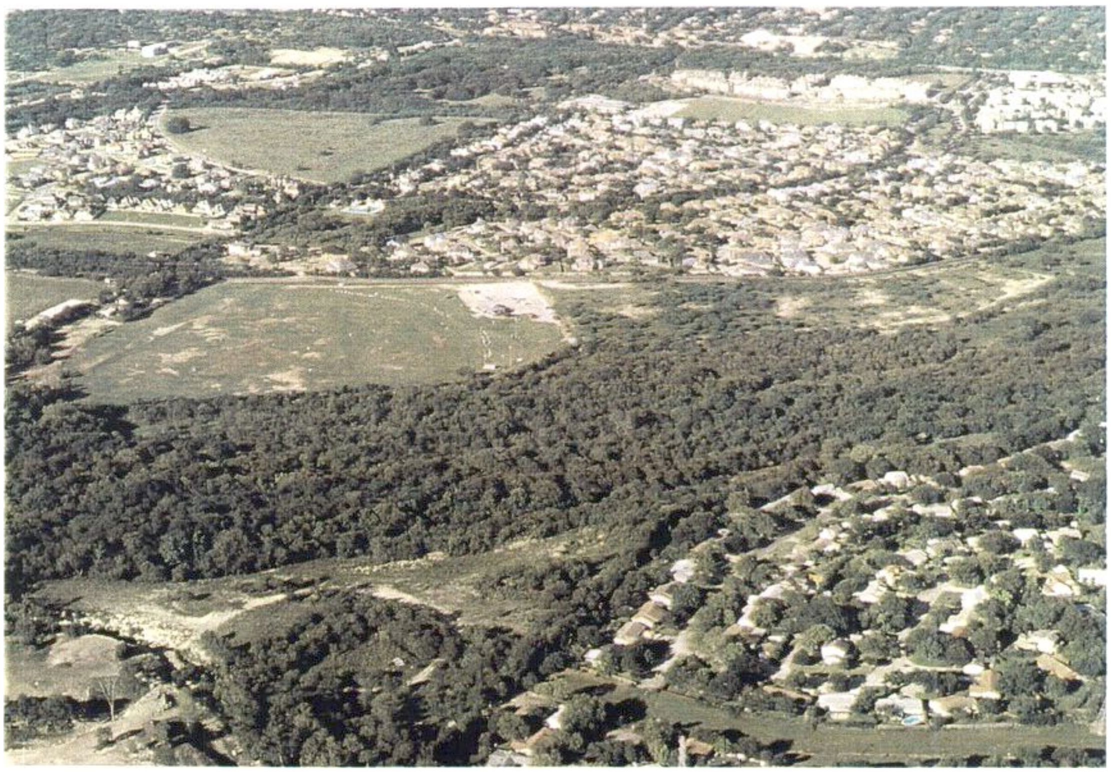
Creek Context
Source: Dixie Watkins, III & Associates

Suburban

The suburban setting is a mixture of developed and undeveloped areas. In general, the density of existing development in suburban areas is less than that of urban areas. More open space is likely available for greenways and trails in suburban areas. The goal of planning and design in these areas will focus on the preservation and enhancement of remaining natural and cultural resources. Figures 3, 4, and 5 demonstrate cross-sections of the natural setting of the three major natural creek types in San Antonio. The following considerations should be incorporated into planning and design:

- Where possible, limits of greenway right-of-way should equal the 100-year floodplain.
- Vegetation will be present, and may have to be carefully reduced to allow trail development while retaining habitat and vegetative cover.
- Preserving and maintaining wide natural floodplains and meanders in creeks will be the priority. This will reduce maintenance of engineered structures and minimize flood impacts downstream.

- Transitions between natural and man-made drainages will be important from both an aesthetic and a hydraulic design perspective.
- The opportunity for coordinating tie-ins with private developments such as residential subdivisions and golf courses will be present in the suburban setting. The public-private partnership is important in developing greenways and trails that serve future development.
- Greenways in suburban settings may come before other development and may spur opportunities for adjacent more intensive parks (i.e. ball fields.)



Creek Context
Source: Dixie Watkins, III & Associates

Rural/Undeveloped

Rural and undeveloped areas require similar planning and design objectives. In these areas, creeks are natural with some possible man-made changes due to irrigation practices for farming or water uses for ranching. The goal of planning and designing in these areas is conservation of lands which are threatened by encroaching suburban development and preservation of land which is yet unaffected by any development. Planning greenways in rural and undeveloped areas may require the following considerations:

- These projects may require special considerations for placing a narrow public park across larger tracts of private land. Right-of-way established for greenways should equal the 100-year floodplain, where feasible. Design should incorporate latest fluvial geomorphogical practices. Design should consider ultimate upstream development for adequate drainage.

- Rather than working to get as much available remaining creek areas included in the project, planning may involve limiting the project to what area is truly significant.
- Animal habitat may be significant and should be preserved. Connections to larger habitat areas should be considered.
- Trail should be segregated from farming and ranching uses.

B. PHYSICAL ORGANIZATION FOR GREENWAY PLANNING

Defining a Greenway Corridor

To begin planning a creek-based greenway, a project corridor should be defined. The definition should allow flexibility during the project development. Most communities who have embraced creek-based greenways have targeted the 100-year floodplain as their principal building block. However, in many cases in San Antonio, the floodplain is either too broad or too restrictive for defining the breadth of a greenway. Again, depending on each segment of a corridor, flexibility is the key. Overall project goals should be defined to keep the project focused. For example, a project goal could be to reduce sediment and trash that are washed into a local drainageway and render it physically unappealing. Another goal may be to link a local school to adjacent neighborhoods. Define a beginning and an end for the greenway. These points will likely serve as trailheads. Define a realistic corridor to ensure that the project can be executed successfully.

Watersheds form the key for the spatial organization and prioritization of creek-based greenways. Within the San Antonio River Basin, inside Bexar County, are twelve principal watersheds (some of which have been "split" into an "Upper" and "Lower" designation). The four primary watersheds incorporating the bulk of the developed and developing areas are Culebra Creek, Leon Creek, San Antonio River and Salado Creek. Supporting these are Cibolo Creek, Martinez Creek, Calaveras Creek, Atascosa River, Elm Creek, Medina River, Medio Creek and San Geronimo Creek. Each of these can be further broken down into smaller subwatersheds by "namesake" creeks. Lastly, detailed catchment areas, or individual drainage areas, are usually less than 50 acres in size and are usually not included at this level of planning.

Table 2 lists the principal creeks. The preparation of individual Greenway Corridor Plans should ideally be organized by subwatershed. However, convenient natural and/or man-made nodes may be more efficient and practical to divide up creek systems within the larger subwatersheds. For instance, the Panther Springs Corridor – from Camp Bullis' eastern boundary to West Avenue, above the Salado Creek Confluence in the Upper Salado Creek subwatershed – would be a logical segment for planning.

Table 2: Watersheds and Their Major Creeks in Bexar County

Watershed	Creek Corridor	USGS 7.5' Map
Calavaras Creek	Chupaderas Creek Hondo Creek Parita Creek	Elmendorf Elmendorf Elmendorf
Cibolo Creek	Clear Fork Indian Creek Meusebach Creek West Fork Cibolo Creek	Bulverde Bulverde Bulverde Bulverde
Culebra Creek	Culebra Creek Helotes Creek Huesta Creek Lee Creek Ranch Creek Reyes Creek, Los Chimenea Creek	Culebra Hill Culebra Hill Helotes Helotes Helotes Helotes Helotes
Elm Creek	Black Hill Branch Elm Creek Live Oak Creek Post Oak Creek	Macdona Terrell Wells Macdona Macdona
Lower Leon Creek	Comanche Creek Huebner Creek Indian Creek	Terrell Wells Culebra Hill Terrell Wells
Lower Salado Creek	Ackerman Creek Beitel Creek Pershing Creek Rittiman Creek Rosillo Creek Walzem Creek	Martinez Longhorn San Antonio East San Antonio East Southton San Antonio East
Lower San Antonio River	Losoya Creek Medina Creek Minita Creek Palo Blanco Creek	Losoya Losoya Southton Losoya
Martinez Creek	Woman Hollering Creek Escondido Creek Salitrillo Creek	Saint Hedwig Martinez Saint Hedwig
Medina River	East Branch Big Sous Creek Live Oak Slough Lucas Creek Polecat Creek Potranco Creek	La Coste Macdona Macdona Macdona Macdona
Medio Creek	Caracol Creek Medio Creek	Culebra Hill Terrell Wells
Upper & Lower Leon Creek	Leon Creek	Southton

Watershed	Creek Corridor	USGS 7.5' Map
Upper & Lower Salado Creek	Salado Creek	Southton
Upper Leon Creek	French Creek Pecan Creek	Culebra Hill Van Raub
Upper Salado Creek	East Elm Creek Elm Creek Elm Waterhole Creek Lewis Creek Lorence Creek Mud Creek Mustang Creek Panther Springs Creek West Elm Creek	Longhorn Longhorn Longhorn Camp Bullis Longhorn Longhorn Bulverde Longhorn Longhorn
Upper San Antonio River	Alazan Creek Apache Creek Harlandale Creek Martinez Creek Olmos Creek San Pedro Creek Six Mile Creek Zarzamora Creek	San Antonio West San Antonio West Southton San Antonio West San Antonio East San Antonio East Southton San Antonio West

Table 2: Watersheds and Their Major Creeks in Bexar County
Source: Dixie Watkins III

Multi-Objective Planning

Greenways should be evaluated from as many corollary perspectives as possible. The ability to analyze and evaluate sometimes disparate factors is critical to making balanced planning, design and management decisions. For instance, habitat conservation may be in conflict with certain recreational uses, and active storm water management techniques might conflict with habitat conservation. Yet, given the breadth and diversity of floodplains, adjacent buffers, and open spaces, these issues can usually be accommodated. It will be essential, for a greenway system design to be truly viable, that the variety of major stakeholders be equally represented as early in the planning process as possible.

Awareness and identification of concurrent development issues can aid greenway development and may assist in assigning development priorities. Greenway projects could be "tacked on" to other improvement projects. For example, a sewer outfall line is being extended up along a potential greenway concurrent with development. Since that requires an easement, which also necessitates the removal of vegetation for installation, why not take advantage of part of this alignment for a pathway? Or perhaps community development money is available for an inner-city redevelopment-drainage project; why not stipulate streamside vegetative restoration in concert with channel improvements? By creatively and comprehensively addressing not only the "standard" greenway issues but also the broader view, many open space connections, neighborhood improvements, recreational, and interpretive opportunities can be realized concurrently. This approach can also save money by adding sometimes small greenway construction scopes of work to larger infrastructure projects. The greenway planner may refer to Parks & Recreation Department's "Creek-Based" Linear Park System Priority Map" to evaluate potential concurrent planning opportunities.

GATHERING DATA

Once the general limits of the greenway are defined, it is time to start gathering information and creating a base map. By gathering and mapping this basic data, the critical components and opportunities within the greenway project can be identified. An overlay mapping technique that puts each basic category on its own layer and then superimposes the layers can define areas where many unique resources and opportunities co-exist.

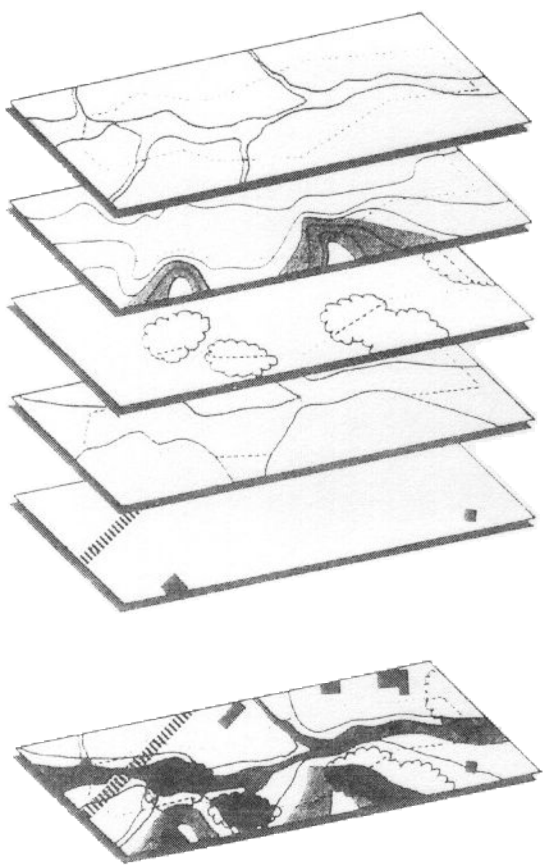


Figure 8: Overlay Mapping Technique
Source: Flink and Searns, Greenways A Guide to Planning, Design and Development, 1993.

Topography

An excellent overview of the project area can be created using topographical data. Topography is generally the slope of the land. This data can be found on U.S. Geologic Survey (USGS) quadrangle maps. Topography is very important for planning the feasibility and design for trails, storm water structures and other management devices, connections to other open spaces and urban areas, and so on.

Storm Water Management

Determine how storm water being managed (by natural or engineered means) in the project area. Perform a walk-through of the project and identify major creek features such as the width and character of the main channel, significant tributaries, problem areas where erosion or sedimentation is occurring, etc. A walk-through after a rain event could be particularly informative. Identify the channel and floodplain. Contact the City of San Antonio to discuss the project area and identify any ongoing or future drainage projects in the area.

Land Use

Identify the general land uses in the project area. The Bexar County Appraisal District maintains records and maps of each parcel of land in San Antonio. It will be critical to the project's success to identify any land acquisition or easements that will be required and to consult the landowners as soon as possible. Landowners should not find out about their properties being part of a greenway project after the project has been planned or designed. They should be made part of the process. Highlight public and institutional lands on your base map for future consideration of trail connections.

Transportation

Since one goal of creek-based greenways is to provide alternative transportation routes within the community, it is important to plot street/highway and other transportation information on the base map. San Antonio has a developing street-based bicycle network which should be related to creek-based greenway trails whenever the two are in the same area. Contact the City of San Antonio for bike lane information. It is also important to make greenway trailheads easily accessible for visitors who have to drive the trail. Finally, where greenway trails cross streets and intersections, safety measures will have to be designed into these parts of the trail. Contact the Metropolitan Planning Organization to learn about future transportation projects and modifications that could impact the greenway.

Historic and Cultural Resources

San Antonio was originally settled along its creeks, which makes these corridors rich in history and culture. Gather general information on possible historic and cultural resources which may exist and could be preserved or restored. Contact the City Historic Preservation Office, library and local universities in San Antonio for this information.

Environmental Hazards

Identify potential past or present environmental hazards that could impact the greenway. In general terms, environmental law is written such that if one encounters contaminated soil during construction of any type, that same party is responsible for properly identifying and disposing of the contamination. This can be a costly and time-consuming process. By researching the project through the City's Environmental Management Office and the local office of the Texas Natural Resource Conservation Commission (TNRCC), a great deal of environmental history can be gathered so that the greenway project can be designed to avoid potentially contaminated areas.

Vegetation and Habitat

It is important useful to plot general areas of vegetation on the project base map as well. Significant stands of trees or potential landscape buffer areas are important. Perhaps there are small pools or wetland areas that would provide scenic picnic areas or vistas while preserving fish and animal habitat. What is the general height and width of the vegetation? Are there any views that should be protected? Will there be sufficient landscape screening of the greenway facilities during winter months. At this stage of the planning process, overall areas and character of the vegetation are sufficient; a more detailed analysis should occur during design.

Community Impacts

Part of the initial data gathering should include identifying key neighborhood and community leaders and groups who will either support or oppose the greenway project. What are the current attitudes regarding greenways and open space preservation in the community? Identify benefits to the community and possible economic development opportunities.

C. CORRIDOR ANALYSIS AND EVALUATION

In order to plan a creek-based greenway, the following five major aspects of the proposed project should be investigated in detail. Below is a checklist for each item. It will be useful to develop a feasibility study that answers the questions below.

Although a particular creek section may rank high on a composite list of candidates for greenway development, the ability to focus on a different segment because of development pressure, water quality issues, or unique linkages to other open spaces should always be considered. Similarly, while prioritizing creeks and floodplains, in their natural state as much as possible, if funding mechanisms become available, highly-impacted, inner-city drainageways which could facilitate neighborhood revitalization should be included.

Storm Water Management

Regional storm water management is important and any specific project must be coordinated with the Storm Water Utility Division to ensure that storm water system needs are met. Greenways improvements can be built to accomplish the following storm water best management practices:

- Preserve floodplain areas along creeks. Wide, natural channels and banks help keep storm water velocities under control. Natural creeks fit best within the natural park setting. Clean and well-maintained engineered channels can accomplish this as well.
- Improve conveyance of storm water by selective clearing of underbrush and cleaning of debris to open the natural floodplain while maintaining its aesthetic and ecological value. Coordinate this activity with habitat preservation.
- Minimize erosion and sedimentation in creeks through the use of vegetation to hold soil in place and to filter sediments out of storm water.
- Detain storm water in low areas developed as park space along linear creek-based greenways.
- What are the channel dynamics? – both hydraulic and hydrological
- What is the impact of greenway development on the watershed?
- Is this project consistent with the Master Drainage Plan for the watershed?
- Is this creek subject to flash flooding in the creek?
- Is the planned development in compliance with the Storm Water Ordinances? What permits will be required?
- What creeks are included in the project? Are they always wet or are they intermittent creeks?
- Where is the creek in relation to the potential trail?
- What type of creek section(s) is (are) present?
- Does the City have available calculations for the 5-, 10-, 25-, and 100-year storm?
- What are the creek velocities? Can the trail practically be outside of the 100-year floodplain? Can it be outside the normal channel? Is this creek subject to flash flooding? What user safety concerns should be addressed?
- Are there existing or planned crossings that can be used for the trail such as low water crossings or bridges?
- Identify perpendicular crossings of local drainage (i.e. tributaries to the main creek). What type of designed storm water outlets connect to the creek?
- Contact Public Works for a list of drainage projects in the planning area.

- Is there a natural low area that is open space and could be used for storm water detention? Contact the City Drainage Department to discuss such opportunities.
- Is the creek routinely maintained? How can a trail be designed to accommodate maintenance?
- Does the pathway also need to serve vehicles doing creek maintenance or just pathway maintenance?
- Is this greenway in the floodplain?
- What drainage calculations will be required by Storm Water Utility Department?
- Is the floodplain contained within an easement?
- Are there any improvements located in the floodplain?

Natural Resources

- Vegetation and Habitat – What are the predominant plant and animal species within and adjacent to the creek, and how intact is the habitat?
- Topography – What are the slope characteristics of the creek's streambed and adjacent landforms and floodplain?
- Geology and Soils – What is the dominant geologic setting and what types of soils are there?
- Hydrology – Is this a "live" creek section, and does it have a significant aquatic and/or groundwater component?
- Geomorphology – What are the physical characteristics of the channel, creekside zone, floodplain area, and potential buffers?

Riparian Vegetation
Source: Dixie Watkins, III & Associates

Cultural Resources

- Archaeological Sites – Are there any known sites previously studied, and if not, what cultural material can be documented?
- Historic Structures – What types, ages, and quality of historically significant structures are present?
- Historic Sites – Are there any significant sites (battles, treaties, famous people…) related to the creek?
- Cultural Landmarks (Heritage Connections) – Are there any significant "connections" to history? (Camino Reales, Indian, scouting and/or cattle trails…)?
- Is/was there any historically significant ranching or farming in the project area?

Prehistoric Rock Shelter
Source: Dixie Watkins, III & Associates

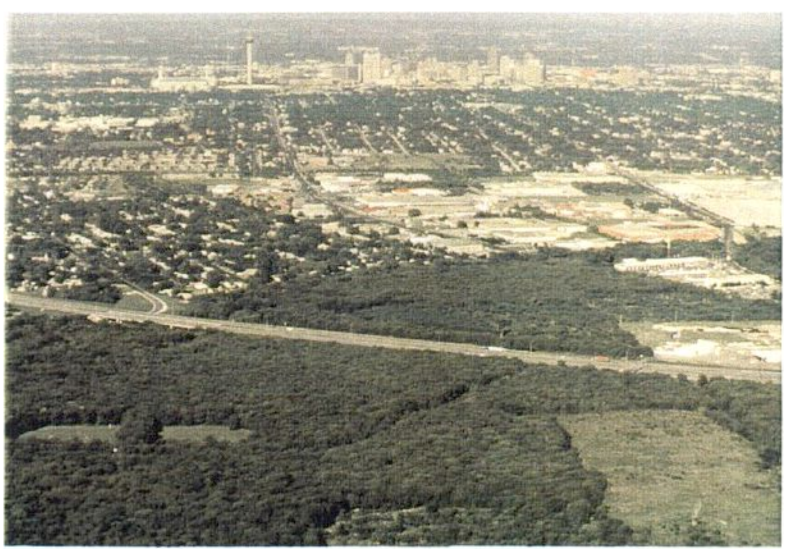
Open Space-Recreational Opportunities

- Existing Parks and Recreational Facilities – Are any of these located on or near the creek, floodplain, or connecting drainageway?

- Public and Quasi-Public Land – Do any other open spaces which may have public use exist nearby?
- Educational Facilities – Are any public or private schools nearby?
- Nature Preserves – Is there a restricted access preserve adjacent to the corridor?
- Linkage Potential (Off-corridor Proximity) – Does this particular greenway segment have either an existing or proposed connection to other public facilities or greenways? (For example: bikeways, street-based pedestrian connections, private recreational sites, public transportation routes, etc.)
- Utility Easements and Rights of Way – Are utility runs or maintenance easements an option:
- Scenic-visual Opportunities – Are there significant views, vistas, panoramas, or unique settings worthy of incorporation?
- Abandoned and Potentially Abandoned Rail and Roadways – Are there existing or unused rights-of-way which could be used?
- What precautions need to be considered to ensure safety of users?

Land Use and Development "Environment"

- Ownership – Who owns the parcels that comprise this section?
- Zoning – What is the zoning, if within the city limits?
- Density, Proximity, and Setback (Adequate Buffer?) – How many dwelling units per acre back up to the greenway, and how close are they to any part of the creek zone?
- Storm Water Interface
- Pedestrian Access – Are there any existing trail connections?
- Vehicular Crossings (Existing and Proposed) – How many, what kind, and where are all road crossings?
- HOA or POA's (Neighborhood Plans) – Are there any approved neighborhood plans available, and how do they relate to the creek?



Example of Creek Context with Land Uses
Source: Dixie Watkins, III & Associates

Greenway Component	Creek Zone			
	Channel Only	Creekside Above Channel	Middle Abutting Creekside	Buffer Outside of Middle
Stormwater Management				
- Detention Basins	U	L	M	OK
- Recharge Protection	U	L	OK	M
- Vegetative Filters	U	M	M	L
Recreation				
- Athletic Fields and Courts	U	L	OK	M
- Trails	L	L	OK	M
- Playgrounds	L	U	OK	M
- Restrooms	U	U	OK	M
- Trash Receptacles	U	U	OK	M
- Picnic Facilities	U	L	OK	M
- Nature Study	M	M	M	M
- Educational Signage	U	L	M	M
Cultural Resources				
- Archaeological Interpretation	OK	OK	M	M
- Historic Site Interpretation	L	L	OK	M
- Community Gardens	U	L	OK	M
- Neighborhood Centers	U	U	L	M
Natural Resources				
- Vegetation Restoration	OK	OK	M	M
- Habitat Preservation	M	M	M	M
- Habitat Restoration	OK	M	M	M
- Aquatic Integrity	M	M	OK	L
- Wetland Preservation	M	M	M	M

M= Most Suitable **OK=Suitable** **L= Least Suitable** **U= Unsuitable**

"For purposes of this Table, Channel is the area carrying most of the water; Creekside is the area adjacent to and above the channel; Middle is the area beyond the Creekside and is equivalent to the 100-year floodplain; and Buffer is the area beyond the Middle. Any improvement in the Middle or floodplain would be required to comply with Public Works Drainage requirements. Floodproofing of elements would be required in the Middle Zone."

Table 3: Matrix of Appropriate Development
Source: Dixie Watkins III and Pape-Dawson Engineers, Inc.

D. CORRIDOR RANKING AND SIGNIFICANCE

Biodiversity and Sustainability

San Antonio has long suffered from treating storm water, and therefore our creeks, as liabilities. The design criteria of getting water off of a site and into all creeks or channels as rapidly and efficiently as possible are contradictory to an ecologically sound greenway program. Even as new drainage policies and sensitivities begin to be assembled, much more still needs to be done. The impact on

Source: Dixie Watkins, III & Associates

floodplains in their natural state from development practices is significant. From the subtle, but cumulative, effect of litter and debris, to conspicuous eroded banks, stripped vegetation, and silt-clogged streams, these are neither healthy nor attractive greenways.

The further drainage policies and practices go towards emulating natural processes and conditions, the greater the net improvement of the greenway system's ecology. The conservation of vegetation and natural landforms, both within the primary channels as well as in the floodplain and its buffers, will do the most in terms of furthering biodiversity and sustainability. The further up the drainageways and watersheds the most fundamental of all best management practices is extended, the greater the overall health of each creek.

Connectivity, Node to Node

Using both natural and designed connections of integral landscapes will also greatly offset development losses to wildlife habitat and water quality. These connections can be made along both biologically and spatially-feasible swaths. And, it has been proven across the country that these can sometimes be relatively strategic in width and length. They may be as little as a wildlife-friendly culvert under a roadway, along a ridge for an arbitrary distance, or as big as a regional nature preserve, or park. In any case, wherever connections can be forged between greenways, both the environment and the recreational potential therein is tremendously enhanced.

Connectivity
Source: Dixie Watkins, III & Associates

The full exercise of this integration is not enabled by either the public or the private sector but both. And, conversely, it is also not just the task of a parks entity, but of all city, county and state agencies working in concert. To make these desirable connections will require a broad vision. This vision is far larger than the scope of a single governmental entity. At a minimum, having requirements that allow the primary greenways to be unified from one node to the next is fundamental. The priority should be first to whole, natural floodplain components, for segments that are defined naturally (headwater to tributary, tributary to confluence, etc.). But, practicality mandates that political boundaries, urban edges, road crossings, community facilities, and so on are just as logical for making these connections.

Allowable Impacts

The extent of any recreational use of any greenway segment will always have to balance the potential benefit of the use against its potential environmental impact. Offsetting variables should therefore be planned for. For example, in a creek system which will be highly impacted by storm water increases and adjacent development densities, greater freeboard for both storm water and human use can offset the degree of impact. By providing more room in the improved greenway for storm water and recreation, through breadth, depth and buffer, both downstream and lateral impacts are lessened.

Also, in the areas of high composite values such as recharge features in the floodplain, adjacent caves, archaeological sites, or endangered species, habitat, provide the basis for planning alternative alignments for recreational uses such as pathways and related activities.

E. POTENTIAL CREEK-BASED GREENWAY CORRIDORS

Included with this document is an overall plan that delineates potential corridors for creek-based greenways in San Antonio and Bexar County. This plan shows locations of major streets and primary creeks in addition to flood zones and existing park facilities. Any potential greenway project should relate to the overall greenway system so that the system is ultimately inter-connected, continuous, and regional.

F. FUNDING GREENWAYS

Along with the basic planning and concept development and preparation of preliminary maps and drawings, funding sources are an integral component of the planning process. Often, applications for funding will require a defined scope and general mapping of the proposed project. Appendix E is a list of federal funding sources for greenway projects. Some local sources of funding include the following:

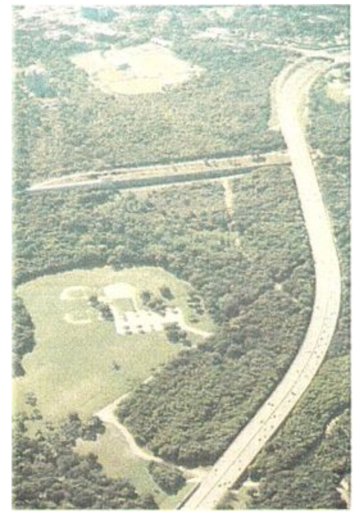
- Local bond issues
- Federal Emergency Management Agency (FEMA) floodplain property acquisition
- Community Development Block Grants
- Property owner and homeowner associations
- City Council funding
- Transportation Equity Act of the 21st Century (Texas Department of Transportation)
- Local grants and foundation funding

III. DESIGN OF CREEK-BASED GREENWAYS

III. DESIGN OF CREEK-BASED GREENWAYS

A. RECREATION OPPORTUNITY IN CREEK-BASED GREENWAYS

Creek-based greenways offer twin opportunities for park development. One, they provide valuable open space, and two, they offer the opportunity for recreational development that takes people from place to place. The feature common to this type of use is a trail. Trails may allow more active and intensive recreation than site-specific parks, and a variety of circulation-based recreation opportunities is possible. Creek-based greenways can also be used for non-recreational purposes, by people who are traveling to work or school, for example. Because most greenway trails can accommodate a mix of user types and activities, careful design and attention to potential conflicts is necessary.



Source: Dixie Watkins, III & Associates

Walking, Jogging/Running, and Wheelchair Rolling

Trail Example
Source: Dixie Watkins, III & Associates

These activities can be recreational or functional and require little support equipment. These activities are appropriate in every instance of trails in greenways. The basic design criterion is the pedestrian scale. Primary considerations for providing for these activities include: pathway surface; pathway gradient; pathway width; sight lines; and amenities. Other considerations include variety of sensory stimuli and environmental ambience.

Street Bicycles

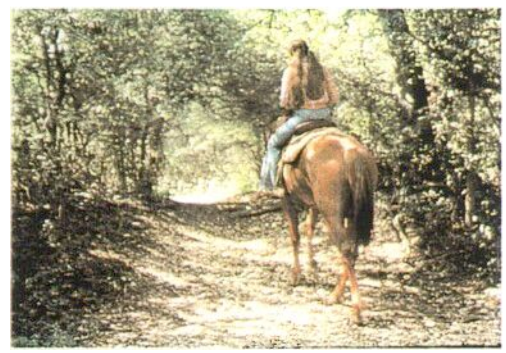
Sometimes referred to as "touring" bicycles, they are restricted by their design to use on improved surfaces. A greenway trail must provide a relatively smooth and continuous hard surface to accommodate these types of bicycles. They are appropriate only in greenways that offer improved trails; neighborhood streets may also be a part of a greenway network in urban areas. Primary design considerations include: pathway width, surface and construction; bicycle speed; sight and stopping distances; curve radii; intersection designs; and safety from hazards.

Mountain and Hybrid Bicycles.

These bicycles allow the rider more flexibility in choice of route. Both may be operated on a variety of surfaces, although only the mountain bike is a true all-terrain vehicle. They share primary design considerations with touring bicycles, although accommodation of these types of bikes in a greenway is a bigger challenge because their use is not restricted to the trail proper.

Skates, In-Line Skates, Skateboards.
As with the touring bicycle, these activities are appropriate only in greenways that feature hard pavements, and share design considerations with both pedestrian and bicycle requirements.

Horseback Riding
Equestrian use is an appropriate activity in a greenway, and special design criteria would apply. Special support facilities, such as stables, trailer parking, corrals, and staging areas, need to be provided. Trail surface material must be compatible with horse traffic, concrete for example is inappropriate. Waste control and disposal is a special maintenance consideration. The dimensional control of a horse trail, especially in the vertical dimension, is critical. Overhead clearance required for a horseback rider is greater than for a pedestrian or bicycle rider.


Horse Trail
Source: Dixie Watkins, III & Associates

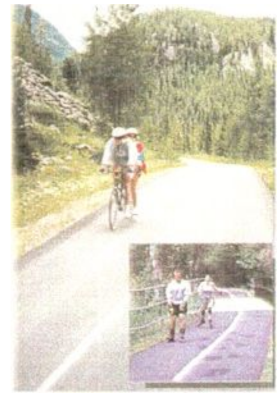
Combining horseback riding with other uses on a shared use bicycle trail is not recommended due to the potential for animal/bicycle conflict. Other uses may also pose conflicts and this should be carefully studied, and adequate space for all uses should be considered. As site conditions allow, providing multiple trails in order to segregate horseback riding in the same greenway is encouraged. Such multiple alternate trail alignments should be designed to be physically separated and clearly signed.

Other
Where trails intersect or terminate at nodes or destinations, there is potential for mutually-supportive facilities or activities. Sharing facilities helps extend the impact of available resources and serves a wider audience of users. Locating restrooms or drinking fountains at nodes can alleviate concerns and costs associated with placing such facilities in more remote areas along trails. Elements that require regular maintenance or that may invite vandalism are better placed where access and security may be more readily available.

Discussion of other movement-based recreation activities would have to include consideration of personal motorized vehicles. Due to concerns for safety and environmental degradation, such activities are generally not wise additions to creek-based greenways. Provision for such activities – such as dirt bikes – may be accommodated at other sites that allow for application of specific design criteria.

B. SHARED USE TRAILS

It is unreasonable to assume that any greenway trail could be restricted to a single use or user type. Moreover, combining activities and user types yields a facility that is more flexible, more cost-efficient, and a wiser use of resources. Although amenities will vary with sites and budgets, trails will be the primary design feature of any creek-based greenway, and most will share activities and user types.



Shared Use Trails
Source: American Association of State Highway and Transportation Officials (AASHTO), Guide for the Development of Bicycle Facilities, 1999

A shared use trail is one that is distinct and physically separated from motorized vehicular traffic roadways. It may occur within a roadway right-of-way, a park or greenway, or within an independent right-of-way, such as a utility or railroad easement. It should be signed and marked to announce the uses that it accommodates, as well as those it does not. Shared use trails may be used by walkers, runners, bicyclists, skaters, wheelchair users, and others. Another option for providing shared use trails is to provide multiple trails in the same general location that might share common trailheads or nodes, but whose routes are physically separated. For example, this could include providing wet/dry trails, i.e. if one trail is impassable due to high water, another may be above it. Another reason might be to separate potentially conflicting uses; signage will be critical to inform users about which trail to use.

Creek Crossing
Source: Dixie Watkins, III & Associates

The trail should be designed to be closed to public operation of motorized vehicles but should accommodate maintenance and emergency vehicles. Curbing alone will not prevent unauthorized vehicular access. Barriers should be designed to protect the trail from unauthorized use by motor vehicles, yet be complementary to the overall design of the area of the trailhead. Careful coordination between types of vehicles and types of trail surfaces is important. Where some trails may be capable of supporting truck and other traffic, others – by virtue of their design – may be capable only of accommodating small cart-type vehicles. Therefore, consideration must be given to selection of trail materials and surfaces, as well as understanding the maintenance requirements so that the trail is properly accessible by the appropriate mix of users and vehicles.

Trail Example
Source: Rialto Studio, Inc.

Types of Users

Depending upon the trail's surface and other design features, any non-motorized user may use a shared trail. In general, users are of two types: recreational and functional. A recreational user – whether a walker, runner or a bicyclist – will use the trail for recreation and pleasure. A functional user will use it as an alternative form of circulation and travel. Although user types share many design criteria in common, each also requires certain specialized attention, discussed more thoroughly below.

Route Selection

By its definition herein, the trail will be contained within the boundaries of existing creeks and other drainageways and park land; in that sense, its route is fixed. However, there is great latitude in how the trail may be configured to fit its site and how it interacts with its surroundings. The selection of trailheads, trail routes, and nodes will be guided by combinations of several criteria: pedestrian and bicycle traffic generators; scenic and recreational amenities; continuity; terrain; adequate space; and constraints.

Also of importance is design consideration where trails have to be routed onto streets. Existing constraints can include such situations as dense surrounding development or the creek being characterized solely by a narrow concrete channel. Such conditions will force the designer to seek alternate routes. Where trails have to be routed onto adjacent streets, attention must be paid to delineation of the trail route from the traffic travel zone, and provision of adequate signage and signalization at trail/traffic crossings.

Connectivity is a key criterion for route selection and trail continuity. If a trail must leave the creek-based greenway due to physical constraints, routing it onto adjacent streets is one option. The designer should analyze other options available, especially the possibility of utilizing existing utility corridors, to provide a continuous trail route. The area is laced with such corridors; due to their size, corridors of widths 75 feet and greater offer the most flexibility for shared use operations, maintenance, and security. The design and installation of a shared use trail in a utility easement should not interfere with the function or maintenance of the utility. Where creeks cross utility easements, and the trail does not have to leave the creek, it would be desirable to design trails that utilize the easement, providing multiple routes and connections.

Connectivity via Utility Easement
Source: Dixie Watkins, III & Associates

Examples of traffic generators, especially for bicycle traffic, are residential concentrations; schools; parks and recreational facilities and other community centers; employment concentrations; and commercial centers. Because bicycle trips in urban areas average 3 – 6 miles in length, generators of these types coupled with a proximal greenway system, afford the user opportunity for combining recreational and functional uses. Linking physically distinct generators together by trails increases the likelihood of trail use.

Amenities not only embellish the attractiveness of the trail, but could provide the reason for choosing to use it. It is reasonable to assume that a scenic and well-maintained trail will be utilized more often than its unattractive and unkempt counterpart.

A trail offering the user an uninterrupted journey from one destination to the next increases the likelihood of its use. A discontinuous pattern of trails is less likely to be used with frequency. For the sake of continuity, interruptions should be minimized by finding alternate routes around them. Unavoidable interruptions, like street crossings, should be designed to allow the user safe harbor and signed, safe crossing areas. Trail design should seek out and maximize the amount of trail that is physically distinct from interruptions; there is safety in fewer crossings. Trails should be continuous and avoid interruptions; however, they should also provide links and access to major roads, nodes and destinations

Trail Examples
Source: Rialto Studio, Inc.

Terrain and site-specific conditions will help dictate the number of users and relative difficulty of travel on a trail. Too many steep grades will deter repeated use of a trail by any but the more hardy of users. Grades should be kept to 5% or less as much as possible, and application of accessibility criteria is mandatory. Circumstances dictating steeper grades should be the exception, not the rule. Route selection and mapping should ensure that grades stay within acceptable gradient/distance ratios. Similarly, trail widths should be selected and mapped so that there is adequate room for the trail and its appurtenant parts, like signage.

Design of a trail system should also consider the impact of constraints that may affect trail layout and even user safety. Physical influences may include elevated roadways, freeways and interchanges, busy streets, and other potential impediments to safe, continuous trail travel. Trails should be designed to eliminate potential negative factors like dead-ends, blind corners, or unlighted or dark areas.

Trail Coordination with Elevated Roadway
Source: Rialto Studio, Inc.

Trailheads

Trailheads will usually occur at intersections with roadways, bridges, or at confluences with other types of developments. Trailhead design should accommodate the largest number of users and will have to comply with requirements for accessibility. Where possible, trailheads should be located at logical points of intersection with vehicular roadways, combining the trailhead feature with a crossing pattern.

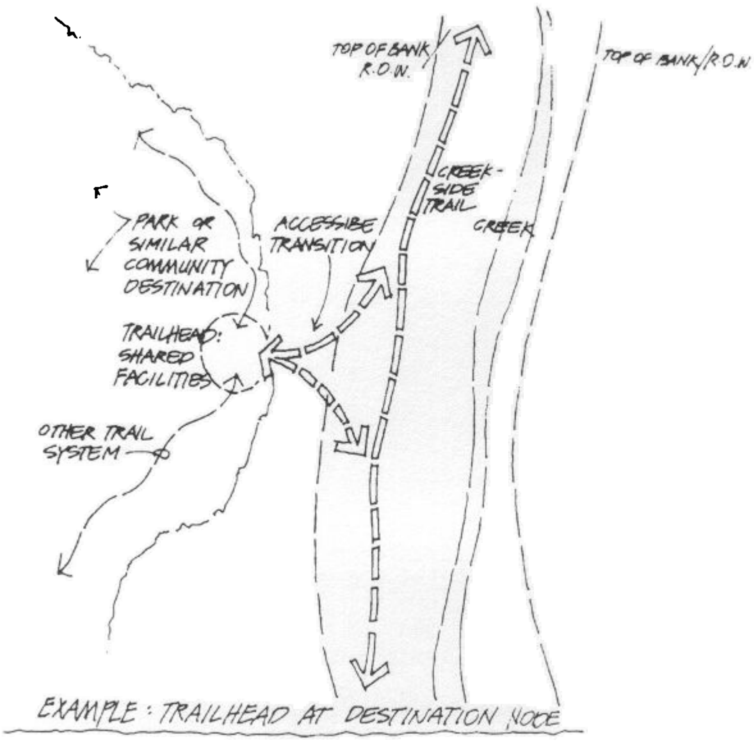


Figure 9: Example Trailhead at Destination Node
Source: Rialto Studio, Inc.

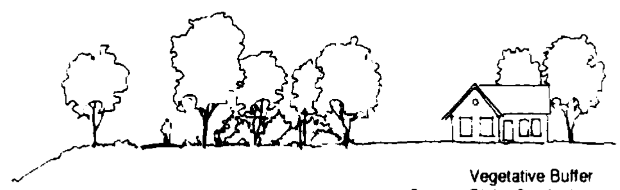
Terrain/Relation to Floodplain

In addition to terrain mapping to ensure that the trail is compatible with its site and surroundings, its relationship to water level, channel, and floodplain extents is important to consider. Where the trail is located within the creek's cross-section will determine its susceptibility to flooding and scouring by erosion. The cross-sectional shape of the channel itself may guide the placement of the trail on one side or another of the channel.

Neighborhood Proximity

Among the connections and generators a creek-based trail system can accommodate, maybe none are more important than residential centers. The trail's potential and availability as an alternative route for recreational and functional travel make it a positive improvement in residential areas. Also, neighborhoods can provide "eyes and ears" for added park and trail security.

However, consideration should be given to trail-to-neighborhood proximity issues so that residents feel secure. Select routes that do not compromise residential privacy. Where trails abut residential areas and where feasible, increased buffer areas, fences or walls, or moving of the trail to an opposite bank of a creek are options for dealing with privacy and security issues. Every effort should be made to provide a buffer between the trail and residential property.



Vegetative Buffer
Source: Rialto Studio, Inc

Where trails are adjacent to neighborhoods, design should include providing access by park rangers and emergency personnel and vehicles for added security. The trail design process shall include a public process for input from adjacent neighbors.

Connections

The following are some of the important destinations for trail users and will require consideration of trailhead design to complement the specific use. They are also themselves generators of trail traffic. Of particular importance is the potential for shared facilities, like restrooms or drinking fountains, so that the trail itself does not have to provide all such amenities.

- Parks
- Schools
- Neighborhood and Community Centers
- Commercial Development
- Public Gathering Places
- Open Spaces
- Other Trails (i.e. Street Bicycle Corridors)

Trailhead
Source: Dixie Watkins, III & Associates

Horizontal Alignment

The horizontal alignment of a trail will rely primarily on the criteria for wheeled travel, as there are specific requirements for design of pavements to accommodate bicycles. The safety of other users can be accommodated by the criteria established for bicycle use. Because bicycles must lean into turns, the relationship between angle of lean and horizontal curve radius is important. For casual or recreational use, the maximum angle of lean is generally 15 – 20 degrees. Through a series of calculations, the angle of lean is translated into curve data. The tables below offer recommended radii based upon lean angles and design speed of the trail. Because the trail also must meet accessibility requirements, a maximum of 2% superelevation is recommended on banked horizontal curves.

Design Speed (V)		Minimum Radius (R)	
km/h	(mph)	M	(ft)
20	(12)	12	(36)
30	(20)	27	(100)
40	(25)	47	(156)
50	(30)	74	(225)

Table 4: Desirable Minimum Radii for Shared Use Paths Based on 15° Lean Angle for Bicycles
Source: American Association of State Highway and Transportation Officials (AASHTO), Guide for the Development of Bicycle Facilities, 1999.

Design Speed (V)		Friction Factor (f) (paved surface)	Minimum Radius (R)	
Km/h	(mph)		m	(ft)
20	(12)	0.31	10	(30)
30	(20)	0.28	24	(90)
40	(25)	0.25	47	(155)
50	(30)	0.21	86	(260)

Table 5: Minimum Radii for Paved Shared Use Paths Based on 2% Superelevation Rates and 20° Lean Angle for Bicycles
Source: American Association of State Highway and Transportation Officials (AASHTO), Guide for the Development of Bicycle Facilities, 1999.

Where site conditions dictate smaller radii than recommended by the tables, signage and pavement markings should be installed to convey warnings about tight curves ahead. Another consideration is to widen the pavement in the curve as much as possible. Where bicycles use a two-directional shared use trail, lateral clearances should be designed based on the sum of the sight stopping distances for each bicyclist traveling in opposite directions around a curve.

Vertical Alignment and Grading

Grades on trails should be designed to allow maximum user potential and enjoyment, yet provide interest and some degree of physical challenge. For compliance with the requirements of the Americans with Disabilities Act (ADA), no trail should exceed a grade of 1:12 (vertical:horizontal). Where a grade of 1:12 is designed, level resting areas are required at regular intervals not exceeding 30 feet apart for ADA-compliant trails. For trails that are more challenging (or not ADA-compliant) the longitudinal slopes may exceed 1:12 and the distances between resting areas may be greater than 30 feet.

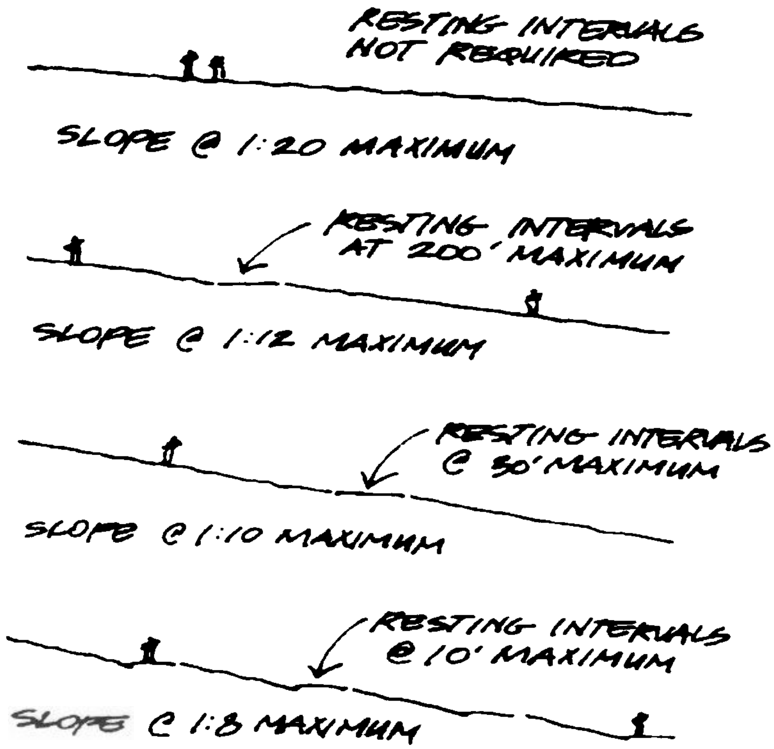


Figure 10: Typical Trail Longitudinal Sections for Non-ADA Compliant Pedestrian Trails
Source: Adapted from American Association of State Highway and Transportation Officials (AASHTO), Guide for the Development of Bicycle Facilities, 1999

Although site-specific terrain might dictate special solutions, generally grades should be held to no more than 5%. This will accommodate accessibility requirements as well as provide safe tolerances for bicycle users (in fact, grades in excess of 5% can be an impediment to many recreational bicyclists.) If grades must exceed 5% in certain instances, Table 5 is a guide for implementation; it is based on bicycle requirements.

Grade Restrictions	Grade Lengths
5-6%	For up to 240 m (800 ft)
7%	For up to 120 m (400 ft)
8%	For up to 90 m (300 ft)
9%	For up to 60 m (200 ft)
10%	For up to 30 m (100 ft)
11+%	For up to 15 m (50 ft)

Table 5: Grade Restrictions and Grade Lengths for Bicycle Trails
Source: American Association of State Highway and Transportation Officials (AASHTO), Guide for the Development of Bicycle Facilities, 1999.

If grades in excess of 5% are necessary, options for mitigating this condition include additional width of trail to allow safe dismount from a bike; signage and pavement markings to announce the steep grade; longer stopping sight distances; longer horizontal clearances and recovery areas; and consideration of trail switchback design to control descent speed. Design of run-off areas at the bottoms of steep grades may improve a trail's safety.

Dimensional Criteria

A shared use path primarily will accommodate both foot traffic and bicycle traffic. For shared use trails with exclusive rights-of-way, the following dimensions are encouraged. Recommended minimum width for a two-directional shared use trail is 10 feet. (If site-specific conditions dictate, 8 feet is the absolute minimum.) If a normal-to-high use is expected, it is recommended that the trail width should be 12 feet.

Minimum width of a one-directional trail is 6 feet. Caution is urged in considering this type of trail, one-directional trails will often be used regardless as two-directional trails. Careful design, attention to signage and trail markings, and enforcement of one-directional travel are some ways to direct proper use of a one-directional trail.

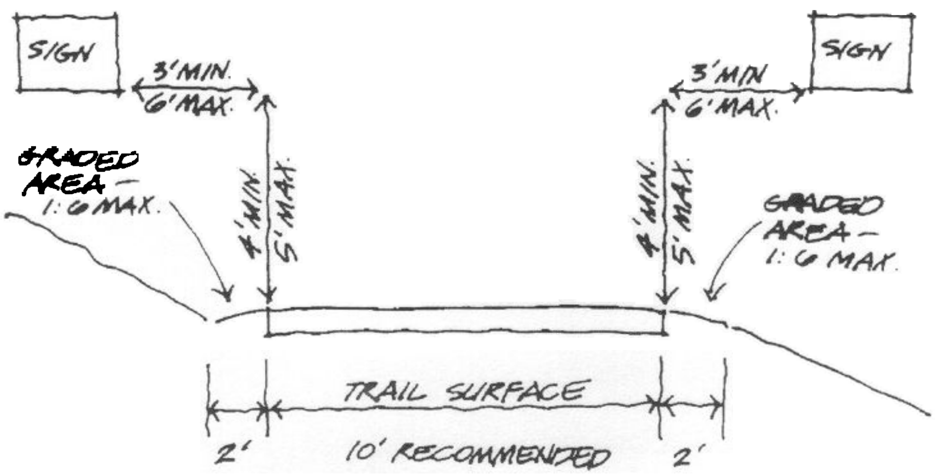


Figure 11: Cross-Section of Two-Way Shared Use Path on Separated Right-of-Way
Source: American Association of State Highway and Transportation Officials (AASHTO), Guide for the Development of Bicycle Facilities, 1999.

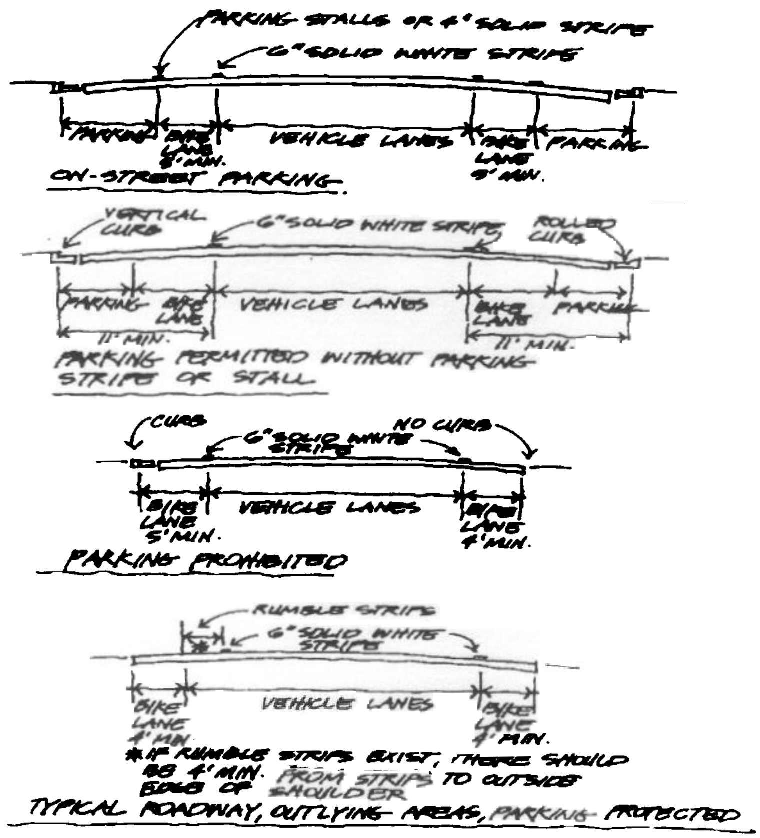
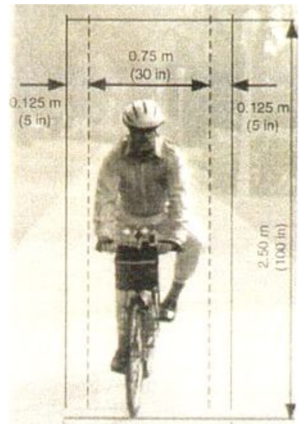


Figure 12: Typical Bike Lane Cross-Sections
Source: American Association of State Highway and Transportation Officials (AASHTO). Guide for the Development of Bicycle Facilities, 1999.

Where a trail shares a right-of-way with a road or is adjacent to a roadway, it should be clearly distinguished from the roadway, whether this is achieved by width, signage, markings, barriers, or a combination. Where this is not possible, and the roadway and trail are less than 5 feet apart, it is recommended that a barrier be placed to provide protection for trail users. The barrier should be 42 inches high, but should not be designed in such a way that it would obstruct sight distances, especially at intersections.

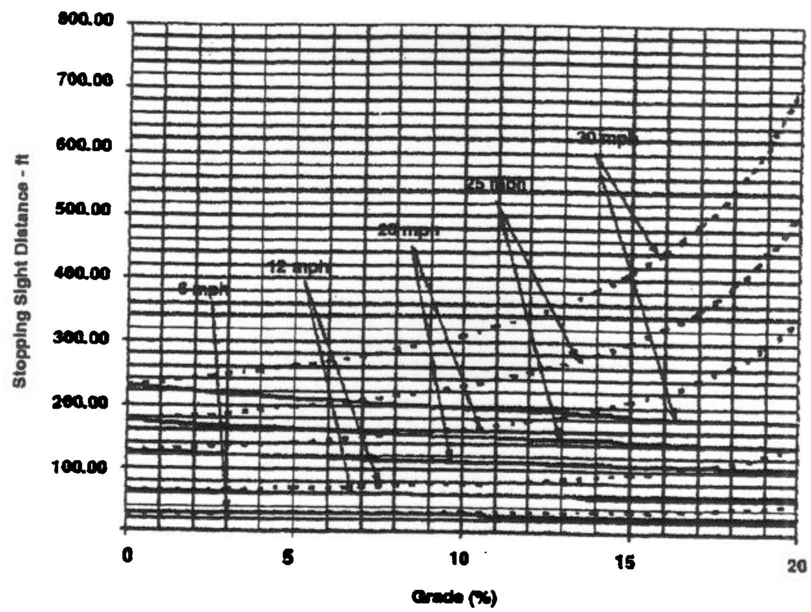
On each side of the trail, a minimum clear shoulder of 2 feet is recommended, with a maximum slope Of 6:1. If site conditions allow, the shoulder width should be 3 feet or more to provide clearance from obstacles such as utility poles, fences, signs, and the like. If the trail is adjacent to a steep slope or waterway, a wider shoulder should be considered. In extreme instances, a barrier may be considered to provide protection, however a barrier placed within the channel must meet criteria as set out in the Unified Development Code. It must also not impede storm flows.

Vertical clearances are also important. There should be a continuous minimum clear vertical dimension over the trail of 8 feet for pedestrian and bicycle users. If service or emergency vehicular access is anticipated, this vertical clearance should be increased to accommodate the vehicle. Emergency vehicle clearance should be a minimum of 14 feet. If equestrian use of the trail is anticipated, the vertical clearance should be designed to a minimum of 12 feet to allow for horse and rider to traverse the trail comfortably and safely. Where trails cross into tunnels or undercrossings, the vertical dimension should be calculated to provide safe clearance, but in no case should it be less than 8 feet (14 feet if emergency vehicles are anticipated.)



Dimensional Criteria
Source: American Association of State Highway and Transportation Officials (AASHTO), Guide for the Development of Bicycle Facilities, 1999

A shared use path should be designed using recommended criteria for stopping sight distances for bicycle users. This will allow for safe approaches to intersections or other stopping points, as well as allowing reasonable reaction time for emergency stops for situations that can be seen ahead.



Descend - - - - - -
Ascend ———

$$S = \frac{V^2}{30(f \pm G)} + 3.67V$$

Where: S = stopping sight distance (ft)
V = velocity (mph)
f = coefficient of friction (use 0.25)
G = grade (ft/ft) (rise/run)

Table 6: Minimum Stopping Sight Distance vs. Grades for Various Design Speeds
Source: American Association of State Highway and Transportation Officials (AASHTO), Guide for the Development of Bicycle Facilities, 1999.

S = Stopping Sight Distance (ft)

20	40	60	80	100	120	140	160	180	200	220	240	260	280	300
											30	70	110	150
							20	60	100	140	180	220	260	300
					15	55	95	135	175	215	256	300	348	400
				20	60	100	140	180	222	269	320	376	436	500
			10	50	90	130	171	216	267	323	384	451	523	600
			31	71	111	152	199	252	311	376	448	526	610	700
		8	48	88	128	174	228	288	356	430	512	601	697	800
		20	60	100	141	196	256	324	400	484	576	676	784	900
		30	70	111	160	218	284	360	444	538	640	751	871	1000
		38	78	122	176	240	313	396	489	592	704	826	958	1100
	5	45	85	133	192	261	341	432	533	645	768	901	1045	1200
	11	51	92	144	208	283	320	468	578	699	832	976	1132	1300
	16	56	100	156	224	305	398	504	622	753	896	1052	1220	1400
	20	60	107	167	240	327	427	540	667	807	960	1127	1307	1500
	24	64	114	178	256	348	455	576	711	860	1024	1202	1394	1600
	27	68	121	189	272	370	484	612	756	914	1088	1277	1481	1700
	30	72	128	200	288	392	512	648	800	968	1152	1352	1568	1800
	33	76	135	211	304	414	540	684	844	1022	1216	1427	1655	1900
	35	80	142	222	320	436	569	720	889	1076	1280	1502	1742	2000
	37	84	149	233	336	457	597	756	933	1129	1344	1577	1829	2100
	39	88	156	244	352	479	626	792	978	1183	1408	1652	1916	2200
	41	92	164	256	368	501	654	828	1022	1237	1472	1728	2004	2300
3	43	96	171	267	384	523	683	864	1067	1291	1536	1803	2091	2400
4	44	100	177	278	400	544	711	900	1111	1344	1600	1878	2178	2500

Shaded area represents S = L
L = Minimum Length of Vertical Curve (ft)
A = Algebraic Grade Difference (%)
S = Stopping Sight Distance (ft)
Minimum Length of Vertical Curve = 3 ft.

Table 7: Minimum Length of Crest Vertical Curve Based on Stopping Sight Distance for Bicycles
Source: American Association of State Highway and Transportation Officials (AASHTO), Guide for the Development of Bicycle Facilities, 1999.

R (ft)	S = Stopping Sight Distance (ft)														
	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300
25	2.0	7.6	15.9												
50	1.0	3.9	8.7	15.2	23.0	31.9	41.5								
75	0.7	2.7	5.9	10.4	16.1	22.8	30.4	38.8	47.8	57.4	67.2				
95	0.5	2.1	4.7	8.3	12.9	18.3	24.7	31.8	39.5	48.0	56.9	66.3	75.9	85.8	
125	0.4	1.6	3.6	6.3	9.9	14.1	19.1	24.7	31.0	37.9	45.4	53.3	61.7	70.6	79.7
155	0.3	1.3	2.9	5.1	8.0	11.5	15.5	20.2	25.4	31.2	37.4	44.2	51.4	59.1	67.1
175	0.3	1.1	2.6	4.6	7.1	10.2	13.8	18.0	22.6	27.8	33.5	39.6	46.1	53.1	60.5
200	0.3	1.0	2.2	4.0	6.2	8.9	12.1	15.8	19.9	24.5	29.5	34.9	40.8	47.0	53.7
225	0.2	0.9	2.0	3.5	5.5	8.0	10.8	14.1	17.8	21.9	26.4	31.3	36.5	42.2	48.2
250	0.2	0.8	1.8	3.2	5.0	7.2	9.7	12.7	16.0	19.7	23.8	28.3	33.1	38.2	43.7
275	0.2	0.7	1.6	2.9	4.5	6.5	8.9	11.6	14.6	18.0	21.7	25.8	30.2	34.9	39.9
300	0.2	0.7	1.5	2.7	4.2	6.0	8.1	10.6	13.4	16.5	19.9	23.7	27.7	32.1	36.7
350	0.1	0.6	1.3	2.3	3.6	5.1	7.0	9.1	11.5	14.2	17.1	20.4	23.9	27.6	31.7
390	0.1	0.5	1.2	2.1	3.2	4.6	6.3	8.2	10.3	12.8	15.4	18.3	21.5	24.9	28.5
500	0.1	0.4	0.9	1.6	2.5	3.6	4.9	6.4	8.1	10.0	12.1	14.3	16.8	19.5	22.3
565		0.4	0.8	1.4	2.2	3.2	4.3	5.7	7.2	8.8	10.7	12.7	14.9	17.3	19.8
600		0.3	0.8	1.3	2.1	3.0	4.1	5.3	6.7	8.3	10.1	12.0	14.0	16.3	18.7
700		0.3	0.6	1.1	1.8	2.6	3.5	4.6	5.8	7.1	8.6	10.3	12.0	14.0	16.0
800		0.3	0.6	1.0	1.6	2.2	3.1	4.0	5.1	6.2	7.6	9.0	10.5	12.2	14.0
900		0.2	0.5	0.9	1.4	2.0	2.7	3.6	4.5	5.6	6.7	8.0	9.4	10.9	12.5
1000		0.2	0.5	0.8	1.3	1.8	2.4	3.2	4.0	5.0	6.0	7.2	8.4	9.8	11.2

Table 8: Minimum Lateral Clearance for Horizontal Curves for Bicycles
Source: American Association of State Highway and Transportation Officials (AASHTO), Guide for the Development of Bicycle Facilities, 1999.

Trail Construction Materials

A variety of materials is available for the finished surface of the greenway's trail. Durable, easily maintained pavements which offer accessibility are the best all-around selection. Site-specific selection of material, however, will depend upon several factors. Type and anticipated numbers of users may dictate the material. Maintenance, and the frequency of it, will inform the choice, and the ease and cost of replacement of trail material should be factored into any decision based on maintenance. If the trail is in the channel and is susceptible to periodic flooding, the material should be selected based in part on the velocity of the flood water. Making the design of the trail, especially at trailheads, compatible with adjacent properties should be considered.

Trail Example
Source: Dixie Watkins, III & Associates

Concrete

The most permanent and durable material is concrete. It is equally suitable for foot or wheeled traffic. It also is a good surface for trails where accessibility is required. It is the most popular material, behind asphalt, for bike trail construction. It is the most expensive of trail materials and the costs of its use should be weighed against the benefits. It will probably require the least maintenance as far as replacement but may necessitate constant maintenance to keep clean of debris. Paths close to channel should be wide enough to accommodate a small sweeper to keep pathway clean of mud and debris. The surface of the concrete should be textured to provide traction and grip, especially on slopes and in wet conditions. Numerous options are available for coloring and finishing concrete for aesthetic and practical purposes (compatibility with adjacent features or glare reduction, for example) Refer to City of San Antonio Standard Specifications for Public Works Construction, current version, for City requirements that might apply to construction of concrete trails. It is recommended that concrete trails be provided in areas with velocities in excess of 6 ft/sec.

Asphalt

The most popular material for bike trails, there are certain considerations that go into its selection. Aggregate selection is important to the degree of surface texture and resistance to stripping. Local standards and practices should inform the selection of the appropriate grade of asphalt cement and aggregates that have proven to be suitable for the area. It is recommended that the designer utilize geotechnical data in support of the pavement design. Asphalt offers the designer a more natural-looking trail that is still very durable. It may require more maintenance in areas prone to heavy flooding. Paths close to channel should be wide enough to accommodate a small sweeper to keep pathway clean of mud and debris. Refer to City of San Antonio Standard Specifications for Public Works Construction, current version, for City requirements.

Cement Stabilized Base

For a trail with more durability than gravel or earth, but without the cost of concrete or asphalt, limestone base material may be placed, depth depending on the site-specific terrain and the intended use. Materials for its installation are limestone base material (refer to Item 200, Flexible Base in City of San Antonio Standard Specifications for Public Works Construction, current version), Portland cement ASTM Type 1 Normal, and potable water. After the base is placed, the cement dust is applied and watered in for a fairly durable finished surface. This material affords a still more natural look, with more frequent but fairly easy and inexpensive maintenance.

Compacted Gravel

Although in certain forms, it is accessible by bicycles, this surface is better suited to recreational foot traffic. Use only where grades are moderate (less than 5%) and where little or no vehicular activity is expected. It will require replenishment periodically, depending on the frequency of its use and the severity of its exposure to erosion-causing conditions. Different materials that support this installation include limestone base and granite gravel. Compacted gravel material is typically composed of sharp, angular pieces of aggregate, well-graded from fine to coarse. Angular pieces are capable of being compacted together for a more cohesive surface. Round gravels will not compact and will not yield a desirable finished grade.

Stabilized Earth or Natural Ground

The most primitive of trail surfaces, it is also the least expensive application. It is more appropriate for use out of the floodplain and in generally rocky areas, suitable primarily for the Edwards Plateau region. It has a more limited application in areas with more plastic soils, such as the Blackland Prairie and Rio Grande Plains regions. Wherever it is utilized, stabilized earth should be designed to avoid steep slopes. It may need bracing with rocks or other materials to prevent washing out.

Natural ground and normally dry exposed bedrock are appropriate trail surfaces in creek areas that are normally dry, and where unimproved surfaces are dictated by location or budget.

Material	Initial Cost	Maintenance Cost	ADA	Durability	Aesthetic Quality
Lime Stabilized Compacted Dirt	Low	High	No	1-2 Years	Poor
Compacted Granite Gravel	Moderate	Moderate	Yes	3-5 Years	Good
Soil Stabilizer and Granite Gravel	High	Low	Yes	5-7 Years	Good
Asphalt	High	Low	Yes	5-7 Years	Fair
Concrete	Very High	Very Low	Yes	10-15 Years	Fair

Table 9: Paving Materials Matrix
Source: Rialto Studio, Inc.

Area	Recommended Minimum Level of Paving
Paths within 10-year Flood Area	Concrete
Paths above 10-year Flood Area	Soil Stabilizer and Granite Gravel
Bridges and Erosion Controlled Areas	Concrete
Paths to Neighborhood Links	Compacted Granite Gravel
Parking Areas at Trailheads	Asphalt

Table 10: Matrix of Paving Materials
Source: Rialto Studio, Inc.

Creek velocities should be a consideration in selecting paving materials to avoid possible vegetative impacts downstream. Velocities in excess of 6 ft/sec will require a concrete trail.

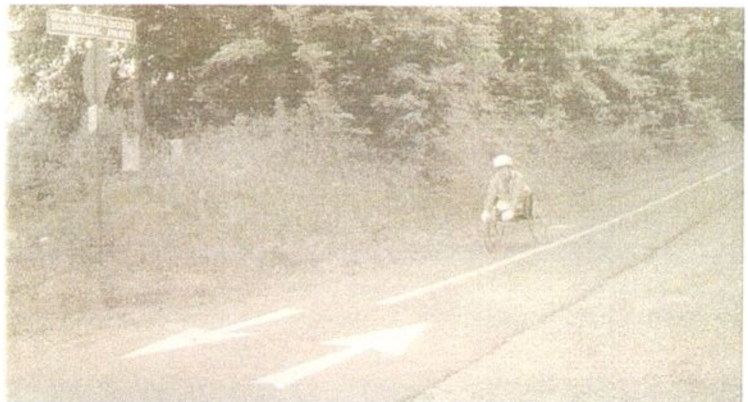
Accessibility

The design of trails must accommodate the greatest possible number of users and should be guided by adherence to standards for universal design. The requirements of the Americans with Disabilities Act (ADA) will be a necessary part of any trail design. The trail design will also have to comply with requirements of the State of Texas Accessibility Standards. Refer to the table below for a general summary of disabilities and design provisions.

	Mobility Impaired	Visually Impaired	Manually Impaired	Agility/ Stamina Impaired	Learning Impaired
Site Organization	Continuous site access network.	Consistent tactile information. Tactile maps and signs.		Proximity of facilities.	Clarity of site organization
Information	Accessibility symbols. Level of accessibility information.	Raised character signs, pictographs. Verbal information.			Pictographs and clear information systems, visual orientation
Vehicle Parking Area	Reserved space size access to paths. Surface type.	Readability of signs.		Distance to facilities.	
Pathways/Trails	5% longitudinal and 2% cross slopes. Width of trail. Surface type. ramp railings.	Path edges delineated with tactile warning strips. Curbs		Rest areas and seating.	Clarity of orientation.
Fishing	Level surface type curbs, rails, shelves, shade & shelter.	Curbs, casting aids, casting space.	Special fishing equipment.	Seating, shade, shelter.	
Boating	Access to boats. Safety of access.	Safety at water's edge.	Access to boats. Operation of boats.		
Restrooms	Accessible to all persons.	Accessible to all persons.	Fixture controls.	Proximity to other facilities.	
Camping & Picnic Areas	Adjacent parking. Type of surface materials. Convenience of utilities.	Tactile warning strips around grills.		Distance to restrooms and water.	

Table 11: Physical Needs of Persons with Disabilities
Source: Flink and Searns, Greenways: A Guide to Planning, Design, and Development, 1993

For a shared use trail to meet the requirements for an accessible route, it must be paved with a hard, durable surface and its longitudinal gradient should not exceed 1:20 (vertical:horizontal) or 5%. (Refer elsewhere in this document for recommended gradients and level resting areas where slopes are required.) The trail should be of sufficient width – 10 feet wide is recommended - to allow comfortable travel and passing by wheelchair and other disabled users. It should have safe access from trailheads and, where feasible, the trailhead should be located proximate to accessible parking. An accessible route must be signed accordingly.



Accessible Share Use Trail
Source: Greenways: A Guide to Planning, Design, and Development / Loring LaB. Scwarz, editor: Charles A. Flink, Robert M. Stearns, authors, 1993.

While a goal of the design of shared use trails should be to make them completely accessible, it should also be recognized that there may be site-specific instances where achieving a fully accessible route is not possible. Examples of this might include insufficient right-of-way to construct proper length of ramp, or trails that are constructed of material other than a hard finished surface, like compacted gravel or stabilized earth. Only in rare, site constraint-driven instances might the requirements for full accessibility be waived. Trails or trail segments that are not fully accessible must be signed accordingly.

Creek/Drainage Crossings

Drainage design criteria must meet the criteria outlined in the Unified Development Code and the Floodplain Ordinance. Exceptions to these criteria should be discussed with the Storm Water Utility Division prior to commencement of the project. Exceptions to the design criteria may be allowed as follows: Criteria for creek crossings and safety may be based on the location of the trail relative to the floodplain. General crossing criteria may be used. Crossings must not adversely impact flood elevations. Crossings will be designed to prevent creek erosion and crossing washout.

Types of Crossings

Creek-based greenways are, by definition, aligned along the flow line of area creeks and drainages. Where trails are constructed, they will interface with these drainages in two basic ways. The trail may have to cross the major creek to get from one side of the creek to the other, perhaps to make a park or neighborhood link or to be in a better alignment. These will be more major crossings. There will also be crossings of the trail over smaller tributaries to the main creek that run perpendicular to the trail.

- **Creeks**
  Creek crossings will vary in size and complexity depending on the size of the creek and the geometry of the floodplain. Crossings over smaller creeks where the 100-year floodplain is fairly confined to the channel may be done with bridges. Bridges should be simple and have as much open space as possible to allow the free passage of water in the event of a major flood. This will also make them safer as open bridges will allow good visibility. Bridges shall also be designed to minimize opportunity for graffiti.

  Creek crossings over larger creeks where the floodplain is fairly wide will have to be designed to provide minimum obstruction to floodwaters. The basic design objective is to minimize the profile of the structure to create the smallest possible obstruction to flood waters. This can be done with low water crossings or bridges which would cross the channel but still be submerged within the floodplain. Bridges above the floodplain would be too long and would likely reach outside the limits of the greenway. Low water crossings should be designed to pass the base flow plus one foot of freeboard or 10 percent of the flow depth (whichever is greater) below the trail. Low water crossings for the trail may also be designed to allow emergency vehicles access in some cases. Bridges can be designed with extra width to eliminate the need for handrails and thereby reduce obstructions to debris carried downstream during a flood. Where there is no base flow in the creek, minimum 24" diameter concrete pipes may be used along the creek flowline to pass low flows under the crossing. Low water crossings in the main creek will be permitted with provisions for safety. These provisions may include warning signs, flood gauges, etc.

  Where practical, and if it does not cause significant interruption to the trail, existing street crossings of creeks should be used for trail crossings. Additional crossings are not desired if existing ones can be used.

- **Drainage Perpendicular to Trail**
  Most tributary crossings will be small local drainages and will, therefore, be confined to a small swale or channel. These tributaries can be crossed with a small bridge or culvert crossing. Crossings must not adversely impact flood elevations. Crossings should be designed to prevent creek erosion and crossing washouts. A 10-year ultimate development flood frequency will be used to analyze tributaries crossing the trail if the crossing is likely to cause backup of local drainage that would impact flooding outside of the 100-year floodplain. Structures crossing tributaries will be modeled with a simple backwater calculation, no flood models will be generated. A 2-year ultimate development flood frequency will be used to analyze tributaries crossing the trail down in the 100-year floodplain. This will be the vast majority of the structures analyzed.